Smart Monitoring of the Consumption of Home Electrical Energy

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Abstract: *The proposed system offers a strategy to control the consumed electrical energy by the home appliances based on the previous power production and consumption statistical database for a case study city. According to the design, the home's appliances are divided into three level of priority but it could be more. In this article a real-time energy consumption manager (ECM) is presented to control the energy consumption based on a storage data and no real time communication is required. The offered system is not only simple and cost efficient but it also needs no grid upgrade or power line communication via the grid.*

Keywords - *component; Energy Consumption Management; Embedded System; Load Curve; Power Grid; Microcontroller.*

I. INTRODUCTION

The installed capacity'sMargins for load peakingcan befrequently utilized as for measuring of generation capability. Latterly these margins can bereduced in some countries in International Energy Agency (IEA),howeverthey are quite comfortable at most countries [1]. Most of the third nation's countries have a lack of the producing power that supplies into houses and the other facilities over a specific time of day, a specific period of the year, or over the whole year. Some countries have strategies to reduce the power production to reduce the production cost or CO_2 emission. Other countries or cities that try standalone or renewable energy are faced with critical situations through a specific period of a year or sudden change in weather.

Abundant efforts would being exerted towards an elevation of clean energiesall over the world for protecting theenvironmental as well as scheduling the consumingenergy configurationfor meetingtheircumulative demands. The shortage in electrical power production in some countries has been one of the major problems facing the daily life of households and businesses. Scheduling of power supply between different areas in the cities has been adapted to deal with the shortage of the power generation in line with the high demand. However, due to the misuse of the public during their time slot of supply and the tendency to over utilize the given period of power supply have been a major obstacle facing the power utility to extend the supply period and improve the delivered power quality.

This research suggests a solution that can be implemented on the individual household level to allow a smart monitoring and control of the temporarily load-shedding of the individual house units' power consumption to see whenever it exceeds the specified limit of power consumption. The specified power limiting can be dynamically set so that it may be increased or decreased based on the available total power assigned to that particular area during specific times of a day or period of a year.

The proposed system is designed to control the consumed energy without needing of a power line communication as in the smart grid. This system has many features like simplicity, low cost, saved data can be updated easy by overwriting the external RAM or by sending an SMS if the GSM optional modem is connected, easy to install and develop as it is based on programmable microcontroller. The residualsections of the manuscriptcan bearranged as follow. In section II, the literature survey is introduced. Sections III presents a case study for a city by day and annual load curve, and in section IV system hardware circuitry is presented. Section V describes the possible load table of priorities. The paper ends with the result and discussions in section VIIVI.

II. LITERATURE SURVEY

The power generation creativitiescould beisolated from the enterprises of power distribution for many systems, the distributionobviously assumes to be full responsible for implementing of the Demand-Side Management (DSM) meanwhile it instantly includesthe consumers of great electrical power [2]. The proposed system assumes that there is a lack of the produced power and the demand side has to reduce the load for a specific time of day or a specific day of the year [3]. Some researchers proposed a prices that depend on strategies of energy control for removing the peaking load with a smart grid. The consumers of energy are controlling their consuming energy to create anadjustment between a cost of electricity and a restriction load costs [4].

Other researchers recommend a schedule techniques of home utilizationsfor implementing demand-side managementswithin a smart grid [5], [6], where growing the request of consumers hadinfluenced the power arrangementseriouslyby means of power generating system appearancesmany challenges together in quality in addition to quantity. The Cost-effective generation witheffective consumingmaybe used for solving these problems in the forthcoming smart grid by integrating with technologies of information besides communication. The smart grids have opportunities for employingvarious pricing systemsthat also benefitsby increased the efficiency of techniques ofutilizations scheduling [7]. In any case, framework multifaceted nature and expense are an imperative matter as well.

A Smart grid could be a perfect solution even with challenges and issues that are discussed in [8], which presents some of these challenges and questions in the concept of smart grid in addition to their solutions. Other researchers suggested employment of a load managing applicationsschemedepend on procedure of a smart grid particularity in energy management facility [9]. In a different approach, the authors in [10] suggested a cloud computing with a centers of data to support smart grid for providing high robustness as well as load balancing.

III. CASE STUDY

As a case study, the system being investigated considers a city with a typical annual load curve seen with Figure 1, and a day load curve seen in Figure2. The annual curve shows a power production shortage from May to September which needs to decrease the power demand below these values. In some countries, the kWH unit cost increases to decrease the load while in other countries like Iraq the city is divided into many sectors. The authority will shut down some sectors to decrease the load but this, of course, will affect the life quality. Similar procedures are adopted through the day load peak. The proposed system presents a new strategy as presented in the flowchart in Fig. 3 which divides the house appliances into three different levels based on their chosen priorities.

IV. SYSTEM HARDWARE CIRCUITRY

The main part of the proposed design is the ATmega32 microcontroller, which manages all the peripherals through different types of communication protocols. As shown in Fig. 4, the microcontroller communicates with the GSM modem via RS232 (TX and RX) @9600 bps. While communication with the real-time controller (RTC) and the external RAM is established through the Inner-integrated protocol (I2C). It also manages a 4x4 matrix keypad through 8 pins and drive the LCD display in 4 bits' mode. This microcontroller has a built-in 8-ADC, so it reads the Current Transformer (CT) conditioning signal to measure the real time AC current value.

A. ATmega32 Microcontroller

The used microcontroller (ATmega32) has all the typical peripheral features that are required by the design like 2x8-bits Timer/Counters with discrete Pre-scalar and associate modes, 1x16-bit Timer/Counter has specification ofdiscrete Prescaler, comparing mode and capturing mode, real-time counter has separating oscillator, four PWM channels, ADC of 8channels, 10bits, byte-oriented twowires serial interface, programmable serial USART, master/slave SPI serial interface, programmable regulator timer with discrete on-chip oscillator. Figure 5 shows the pin connections of the peripherals with the microcontroller and Table. 1 shows the signal line configurations.

B. Load manager

The main power will supply the facility load though three relays which control the load based on the different priorities.

C. Real Time Controller (RTC)

This unit is responsible for managing the time over the day and date over the year. The used RTC (DS1307) has a consecutive realtime clock (RTC) with small power, filled binary-coded decimal (BCD) clock per calendar in addition to 56 bytes of NV SRAM. Addresses and data can betransmittedsuccessivelyover an I2C, bidirectional bus.

The clock per calendar displays values in sec, min, hour, days, months, and years. Alast date for the month beregulated automatically with any month that have less than 31 days, containingmodifications for jump year. A clock formatcan be either the 12-hour or 24- hour with an indicator of AM/PM. The DS1307 have anin-builtsense-power circuit whichsensesfailures in power and spontaneouslychangesfor backing-up supplying. The operation of Regularitymust be continueddespite the partsdrive from the standby supplying.

D. External RAM

According to the design, the load is a matter of time Load (nT), where n representsa number of the sample/year and T will be the time between samples. The system is designed to save a sample every hour through the year that makes n=365x 24 = 8760 and T= 1 hour, it could be more or less as a matter of accuracy. Each sample will be saved in format "XX. XX" A. This format is saved in two bytes to make the RAM > 17520 Bytes or equal to 32KB.

The system uses 24FC512 which has good features like alone supplying with an operation of less than 1.7v, CMOS Technology of low-power, two wires Serial Interfaces, I2C™ compatible, can be cascaded to more than eight devices, inputs of Schmitt trigger for suppressing noises and 100 kHz as well as 400 kHz compatible Clock.

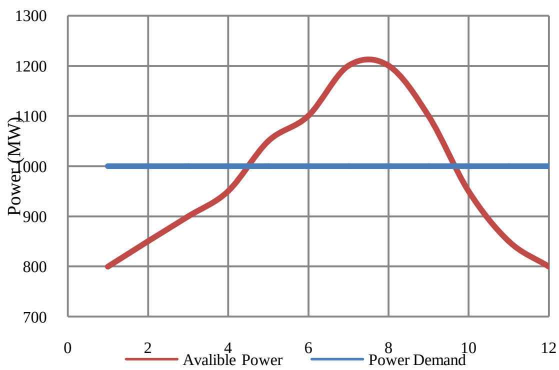

Fig. 1 Annual load curve

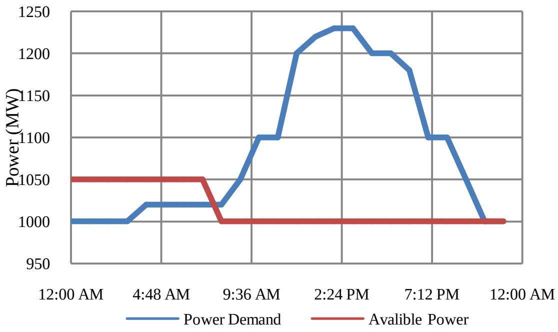

Fig. 2 A day load curve

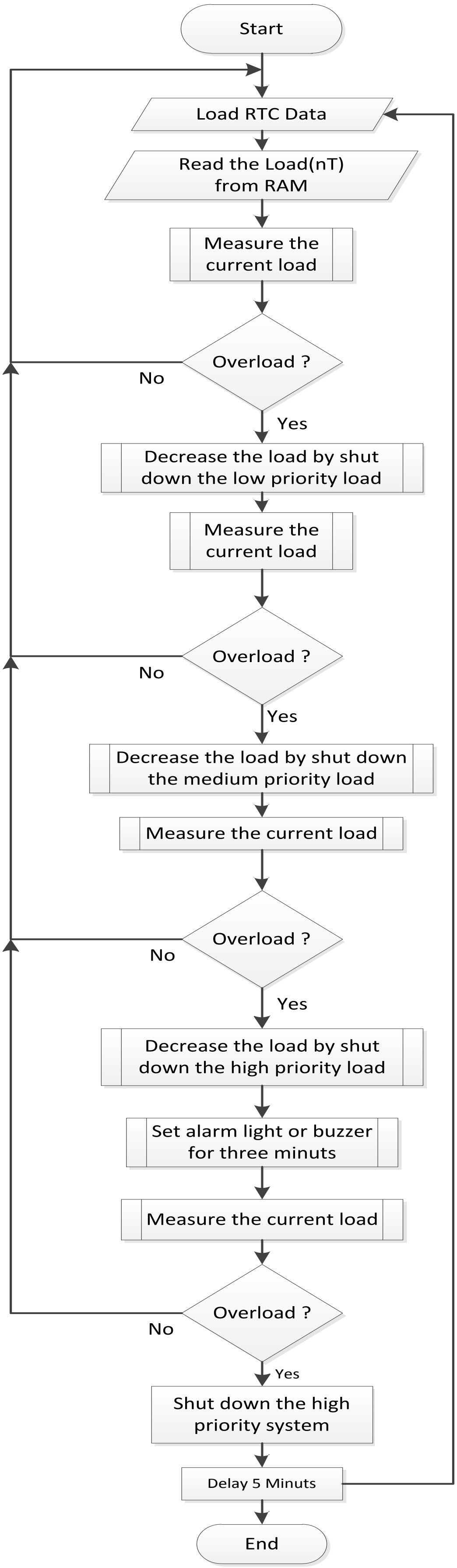

Fig. 3 Flowchart for the proposed software

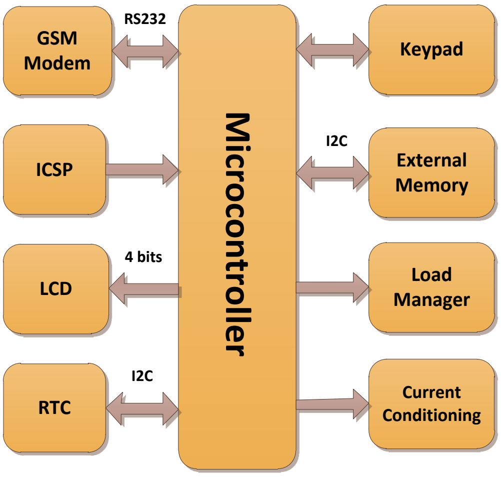

Fig. 4 System Block Diagram

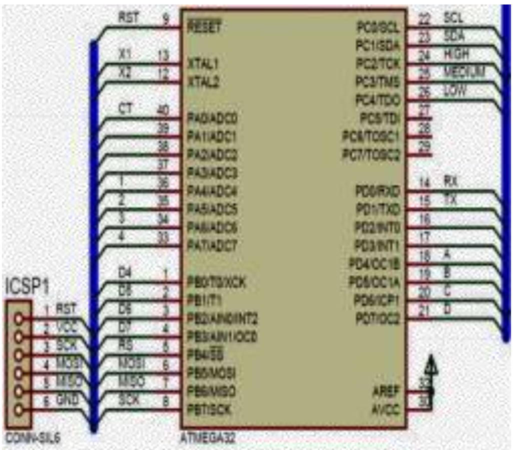

Fig. 5 Microcontroller Pin Connections

Table I. Signal Line Configurations

Used Labels	Pin No.	Descriptions
RST	9	Connected to push button to reset the system.
X1-X2	13-12	Crystal (20MHz)
CT	40	Current Transformer Conditioner signal
1-4 A-D	33-36 18-21	4x4 Keypad
D4-D7, RS,MOSI	1-6	LCD Screen, MOSI as EN signal
SCL SDA	22 23	I^2C serial clock I^2C serial data For external RAM & RTC
High Medium Low	24 25 26	High priority relay enables Medium priority relay enables Low priority relay enables
RX TX	14 15	RS232 received data RS232 transmitted data For GSM Modem
MOSI, MISO, SCK	6,7,8	For programming purposes ICSP1

E. Display

This LCD displays (2x16) characters for the instant load and the allowed load. Fig. 6, shows the connection of the LCD and displays the data in two rows. The first row displays the load demands current (ID) while the second row displays the maximum allowed current at this instant.

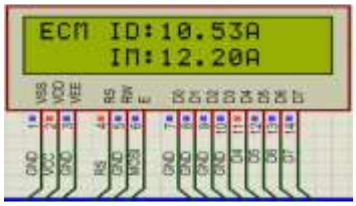

Fig. 6 LCD Screen (2x16 characters)

F. Transformerless Power Supply

The design adopts a transformerless power supply that uses a parallel RC to reduce the voltage through 1A fuse. This stage is followed by bridge for rectification regulated at 5Vdc.

G. Currenttransformer and conditioning

A current transformer (CT) as shown in Fig. 7, can be utilized for measuringan AC current. The transformers of current, and thetransformers of voltage (VT or potential PT) together, can beidentified as instrument's transformer. If the current within the circuit bevery high for applying directly to measure instruments, thetransformer current may produce a reducing current exactlyrelated to the current within the circuit, which may be appropriatelylinkedwith a measured and recorded instruments. Thetransformer current separates the measured instruments from anytoo high voltagesat the monitoring circuit. The transformers of Current are normally utilized in metering as well asprotecting relays in the electrical power industries.

Fig. 7 Current Transformer

The system uses a CT with transfer ratio (100-1) so the maximum output current I_{out} will be 1A if the input current I_{in} equal 100A according the Eq. (1).

$$I_{in} * N_p = I_{out} * N_s \quad (1)$$

The CT is terminated with a 3.3Ω/1W resistor to convert the current to voltage and scale up the current value. It sounds safe now and the converting ratio is 3.3V to each 100A. A 5.1 V Zener diode is connected in parallel with the resistor for over voltage protection.

V. LOAD MANAGEMENT

To manage the load in case of produced power deficiency; the system will take into consideration the different levels of priority. It checks the demand load periodically for overload conditions. If the load exceeds the allowed limit, the systemwill then shut down the low priority appliances andrecheckagain. The same procedure will be repeated with the medium priority appliances.

In case the produced power fails to cover the high priority load, the system will alarm or send an SMS to the house owner to reduce the load manually, otherwise, the system will shut down the entire house after three minutes. After that the system returns the high priority back to check again and this procedure will be repeated three times. If the check fails, the system will be put in shutdown state until the produced power is able to cover the demand load. The system memorizes the house power demands and turns on the other appliances when there is an available power. The priority levels are a matter of the user consideration, however, it may be classified as shown in Table II.

Table II List of Load Priorities

Priority Level	Appliances
High Level	• Security System • Smoke alarm • Emergency light and all other important appliances
Medium Level	• Air conditioning system • Refrigerators • Water heater, etc.
Low level	It could be any appliance that are not affected by losing power.

VI. RESULTS AND DISCUSSION

The system was simulated using the Proteus Software. This program simulates all the used components including the microcontroller. As shown in Fig. 8 the simulated circuit is divided into different sectors. The keypad which is optional is plugged in only in the initialization phase. Fig.9 shows the cost-efficient system dual layer printed circuit board. The prototype cost ≈ 52 USD which could be much less for the mass production. The PCB and component installation cost ≈38 USD, so the total cost ≈90 USD. GSM modem and Keypad cost are optional but they cost ≈ 35 USD. Finally; the PCB is displayed in 3D mode as in Fig. 10 which is based on minimum size.
The proposed system is cost efficient, no smart grid communication is required, easy to install, small in size, lightweight, easy to develop since it is based on programmable integrated circuit (MCU), GSM based and dynamic data about the available power.

COMPETING INTERESTS

The authors declare that they have no competing interests.

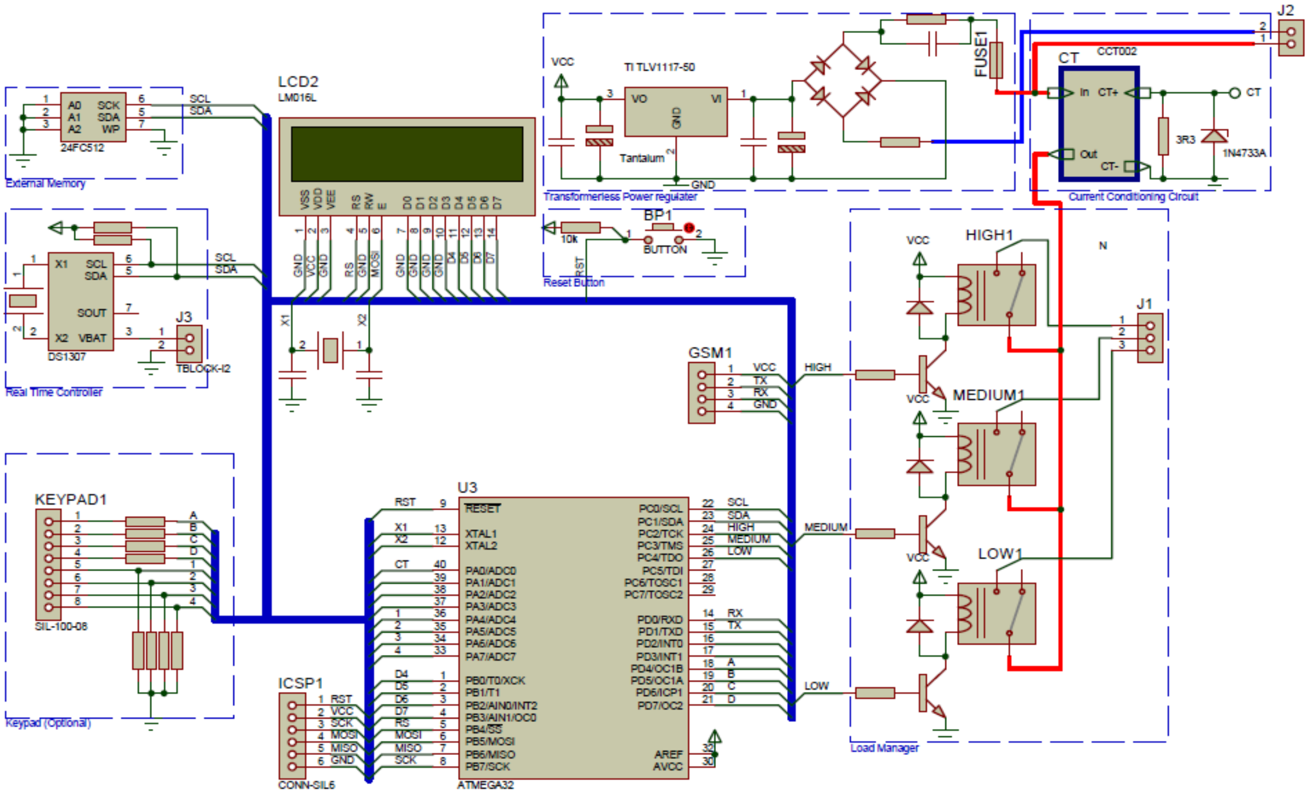

Fig. 8 System Hardware Circuitry

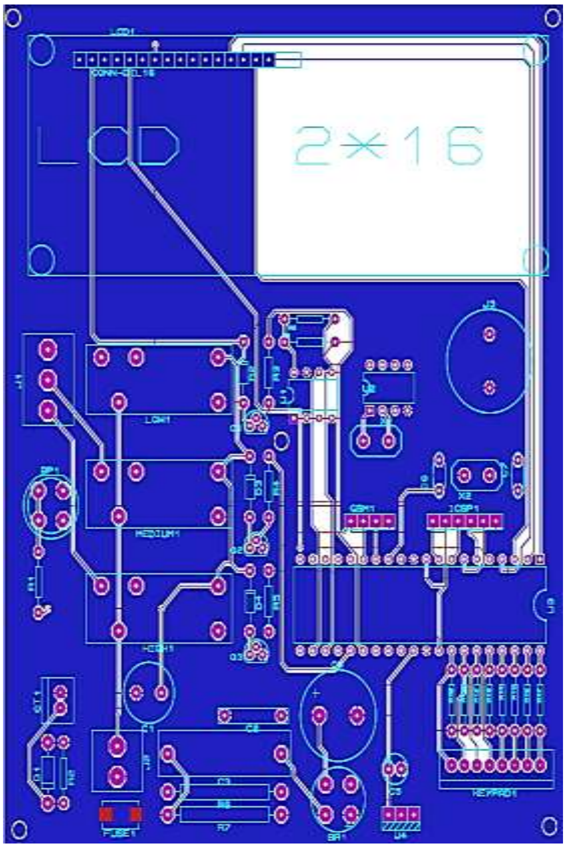

Fig 9The System Printed Circuit Board

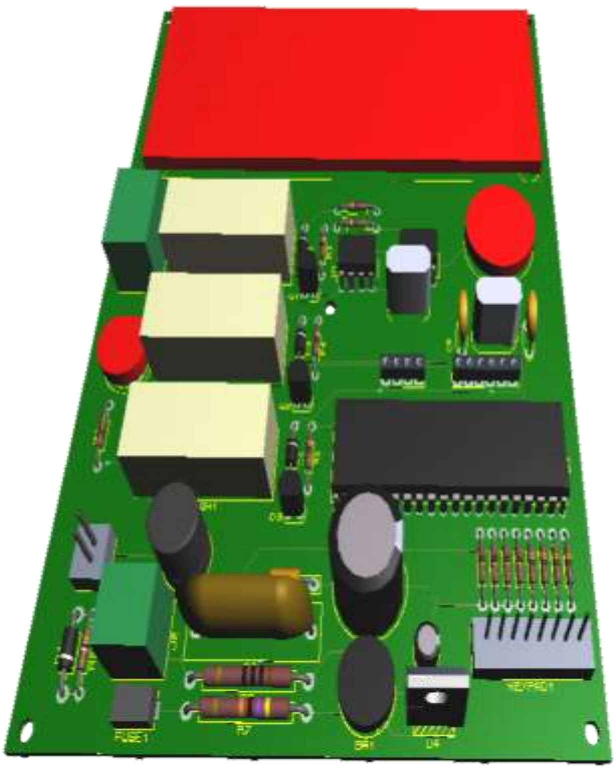

Fig. 10 System 3D Circuit

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