Cost Effective AMR and System Energy Distribution Using GPRS and PLC

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***Abstract*— This system solves the existing problems regarding energy distribution and monitoring. It monitors the meter readings continuously. A Power Line Communication (PLC) based modem is integrated with each electronic energy meter. Communication between meters and coordinator is done through PLC. Coordinator uses a GPRS modem for uploading /downloading data to/from internet. The Billing point at the other end consists of a personal computer with internet connection which contains the database. Live meter readings are taken periodically and are sent to the central database. At the user end an interactive, user friendly graphical interface is used. Energy consumption, billing details, average statics and government notices are available here. The distribution system is more intelligent since loads are divided as critical and non-critical loads. Prior information regarding the load shedding also can be done. Implementation of add-ons such as energy demand prediction, real time dynamic tariff prediction is easy.**

Keywords—AMR, ATmel AVR, Dynamic tariff, Energy monitoring.

I. INTRODUCTION

India has world's 5th largest energy distribution system with a capacity of 228.722GW. And total expenditure is about 12.58 trillion rupees. But 90% of the total energy is being wasted during production, transmission and consumption. Energy theft is another big problem. We have also seen the 2012 India blackout, which affected more than 300 million people in Punjab, Haryana, Uttar Pradesh, Himachal Pradesh and Rajasthan states on 30th July 2012. It is sad to realize that India lack an efficient energy distribution and monitoring system.

Design of an energy monitoring system is presented in this paper. For automated billing and monitoring, the system is associated with GPRS module, web interface and Power Line Communication. This system replaces the traditional meter reading methods and it can enable remote access of existing energy meter by the energy provider. And monitors the meter readings regularly without human effort. ATmega8 is used as the processing unit in the energy meter. This helps to make use of electronics in multidisciplinary projects more accessible.

Communication is done through PLC. It uses a single conductor which can transmit data and AC electric power simultaneously. It is also called as Power Line Digital Subscriber Line (PDSL), power line carrier, Power Line Networking (PLN), mains communication, or power line telecommunications. Power line communication has a wide range of applications, ranging from home automation to Internet access which is often called Broadband over Power Lines (BPL). PLC technologies include: using one type of wire (wiring within a single building), which crosses between two levels (eg: both the distribution network and premises wiring). To form very large networks, multiple technologies have to be used since the transformers prevent the propagation of signals. According to the situation data rates and frequencies also should be varied.

II. PROPOSED SYSTEM

The block diagram of the proposed system is shown in Fig1. Communication between the coordinator and respective energy meters is done through PLC. Coordinator, which is controlled by the controlling station, collects the meter readings from each meter. Actions include connecting and disconnecting loads, displaying tariffs etc. The number of customers and the geometrical distance determines the number of coordinators in the system.

Updated readings from the coordinator can be instantaneously monitored in the controlling station. Power consumption of individual users, their history, instant billing and disconnection/connection of users are also available here. The main parts and features of the entire section are given below.

A. Metering Module

Each metering module consists of a metering IC, a microcontroller, and Real Time Clock (RTC). According to the power consumption Metering IC will generate pulses which will be processed by the microcontroller and stored in memory. RTC is a computer clock that keeps track of current time. It is low power device. RTC counts seconds, minutes, hours and days.DS1307 is used which has advantages such as low cost, easy to solder and improved life time.

B. Coordinator

A single coordinator is connected to a number of meters through Power Line Communication. Internet access is possible with the help of GPRS modem. With the help of an additional meter, total power distribution to a particular area can be calculated. Energy theft detection is possible by comparing this value with sum of individual readings. The maximum number of

meter that can be connected to a single coordinator depends on the distance between them and physical conditions of the area. The coordinator and a group of meters together known as a cluster. Coordinator section contains the microcontroller and GPRS module . AT mega8 is used as the processing unit in coordinator also.

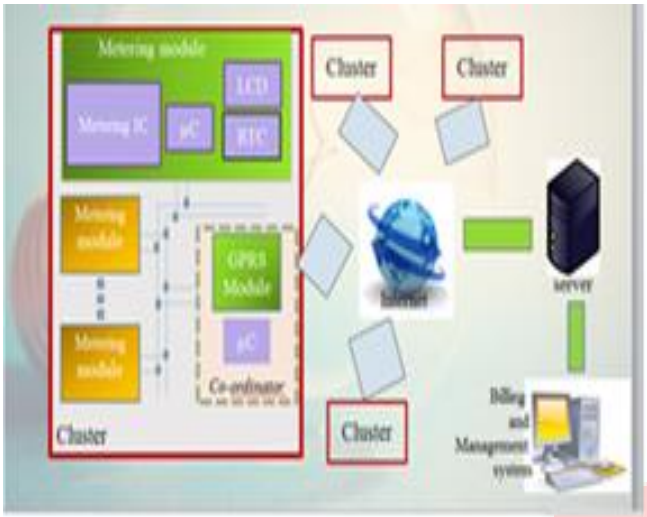


Fig.1 Block Diagram of proposed system

C. Server and Management System

The centralized controlling part is server and management system which is located at the electricity board. All data from individual energy meter will be available here. The officers can easily view, analysis and control of each individual meters are easier for the officers and the connection and disconnection can also be done remotely. Each customer will be provided with an individual ID. Online payment and other options make the system more feasible.

D. Critical and Non Critical Load Separation

The entire load can be divided into two: critical and non-critical loads. These loads can be controlled independently by the system. This system has the ability to control these loads independently. Critical loads include very low power devices such as CFL lamps. If power shutdown occurs, the critical loads can be remained on. Hence the user's basic requirements can get satisfied. And the power wastage can be reduced to an extent.

E. Energy Theft Detection

Energy theft detection is possible with the help of auxiliary meters by comparing the auxiliary meter reading and the sum of other meter readings. The coordinator does this comparison and makes a decision. If the difference is approximately zero then it is an indication of no theft. By including sub meters if necessary, energy losses also can be found out. This concept is depicted in Fig.2.

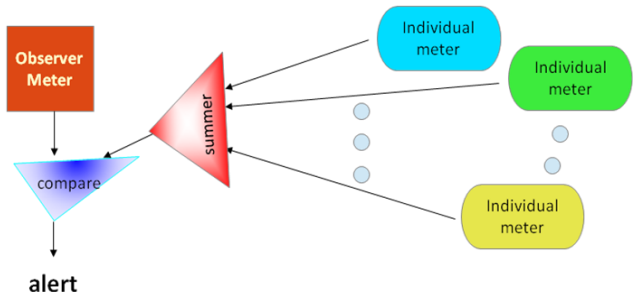


Fig.2 Energy theft detection concept.

F. Real Time Dynamic Tariff

The production of energy is static. But the load requirement is not balanced and it varies randomly. Hence the government faces power shortage problems. To maintain a stable distribution system we have a continuous interaction with the meter. And the tariffs can be varied instantaneously which can be displayed in the meter. Tariff can be increased When the demand is high. Then consumers will be trying to reduce the energy consumption. When demand is less, then tariff also will be reduced. Hence the consumers can increase their energy consumption. By implementing this concept, the stability can be improved and the grid can be balanced. For example it is better to power on mixer grinder, iron box etc. during day time rather than at night since it is the peak time.

G. Demand Analysis and Prediction

The distribution system is more reliable and stable, since statistical method is used to approximate the load requirements with the available data such as time based, area based and season based statistics.

III. HARDWARE DESIGN

The design of entire hardware section includes two sub divisions- design of meter and design of coordinator. Number of clusters defines a system which consists of a coordinator and the associated energy meters.

A. Design of meter

Energy metering IC MCP3905 is used ,which can supply a frequency output proportional to the average active power, as well as a higher-frequency output proportional to the instantaneous power. The available data will be processed by the microcontroller unit (MCU). The power supply for the microcontroller and other devices will be available from AC to DC adapter or from direct ac lines through voltage regulator.

B. Design of Coordinator

Coordinator is the main part of the system. It takes the meter readings regularly and updates the data to the server. Coordinator consists of a microcontroller, Real time clock, FSK Modulator and demodulator, Amplifier, MUX/DEMUX circuit, Isolator circuit, GSM/GPRS module and LCD. Fig.3 shows the

complete schematic of a coordinator. Simulation of the circuit is done using proteus software. This software is used for microprocessor simulation , schematic capture and printed circuit board (PCB) design.

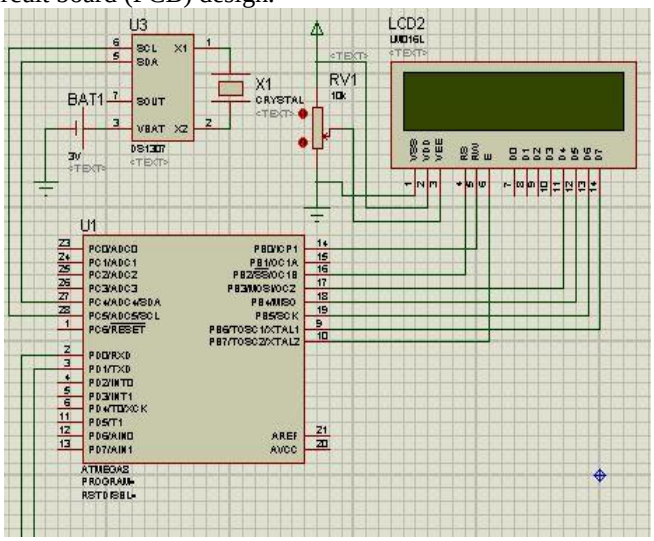


Fig. 3 schematic of coordinator section

ATmega 8 which is a Low-power 8-bit Microcontroller with Advanced RISC Architecture is used here. This high performance microcontroller is interfaced with an RTC by I2C protocol. RTC can count even year with leap-year compensation valid up to 2100. DS1307 is used here as RTC .It has many advantages such as low cost, easy to solder, and can run for years even on a 3V CMOS battery which runs continuously even in power failure.

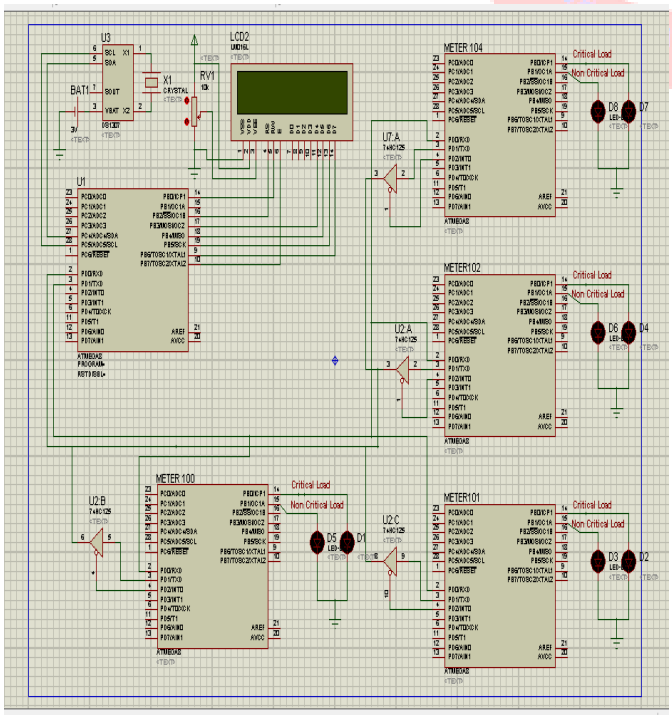


Fig. 4 schematic of the entire system.

The UART data should be modulated, amplified and isolated before connecting to the AC lines for power line communication. The Tx pin of the microcontroller and the modulator input are directly connected. CD4046 is the IC used. It has 2 phase discriminators and one VCO. FSK modulator and demodulator circuits are shown in Fig 5 and Fig 6.

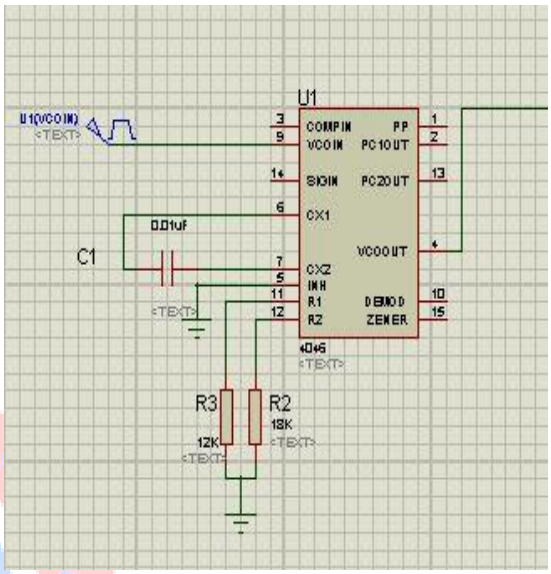


Fig.5 FSK modulator

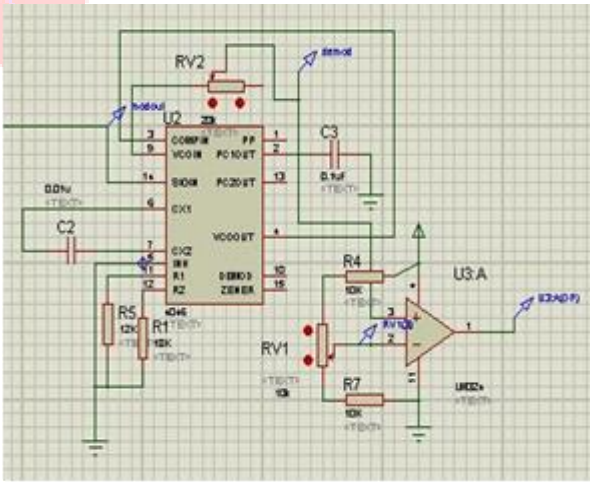


Figure.6 FSK Demodulator

Since Atmega 8 is having only one UART, it cannot communicate with the power line and GPRS simultaneously. By using a multiplexer this problem can be solved. Use of a buffer 74HC125 can achieve this. A simple mux/demux circuit usingbuffer is shown in Fig. 7. U1A and U1B functions as the demux and U1c and U1D as the mux. Switch will generate the

control signal for the buffers. Output of the mux will be available at the node U1D(Y).

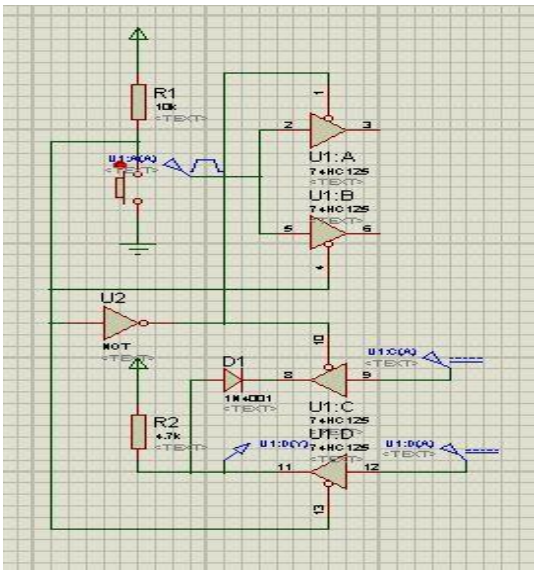


Figure.7 MUX/ DEMUX circuit

IV. PLC Algorithm And Protocol

Certain set of conditions and rules should be obeyed for establishing a reliable power line communication and an efficient monitoring system. Fig.5 shows the Power Line Communication Protocol used.

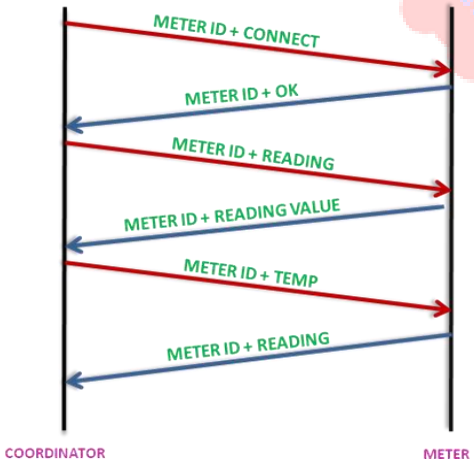


Fig.5 Power Line Communication Protocol

1. [MeterID]+CONNECT : Indicates that a particular meter is trying to get connected.
2. [MeterID]+OK : Conformation signal that the meter is ready for communication.
3. [MeterID]+READING : Requesting for the meter reading..
4. [MeterID]+VALUE : sending the meter reading.
5. [MeterID]+TEMP : request for resending the reading for conformation of the value.

If the conformation signal is not received then the first message will be sent again. If the retry exceeds the maximum limit, then the system reports that the particular meter is out of order.

The last three steps will be repeated three times to check whether the readings are matching. Otherwise coordinator informs us that the system is malfunctioning. The algorithm for establishing the protocol is given in Fig 5. Meter and coordinator algorithms are shown in Fig 6 and Fig 7. The updated data will be continuously displayed on the LCD.

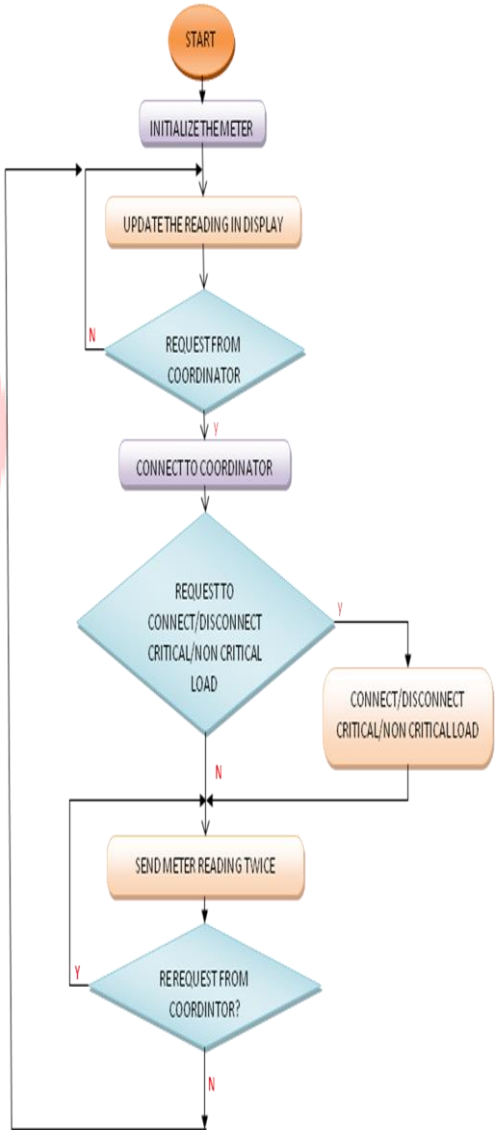


Fig.6 Meter algorithm

Coordinator algorithm is little complex. Because it has to start all the communication since it is the master. . 'Try' is an integer indicating the number of tries it takes to get connected to the meter and'attempt' indicates the number of times it waits for a correct reading. When these values exceed some threshold value, the coordinator will send the message to the controlling station. If the devices are functioning properly, then it can easily get connected and can take the accurate readings.

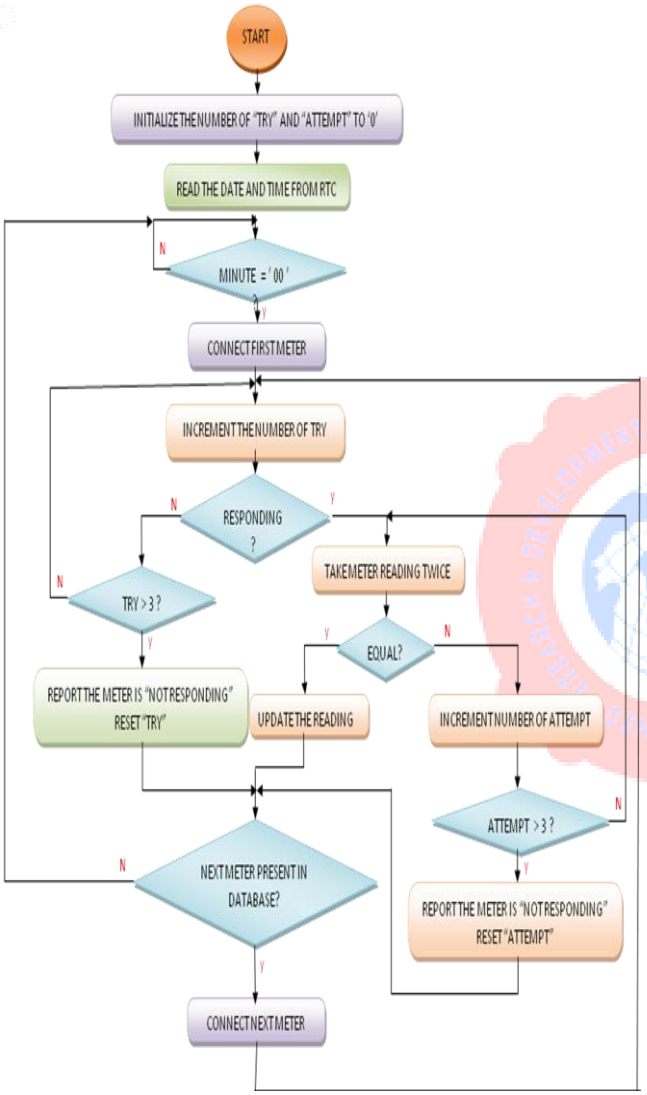
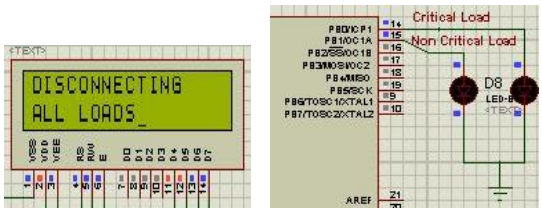


Fig.7 Coordinator algorithm.

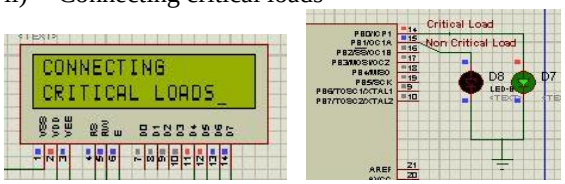
V. RESULTS

The functionality of the entire system and communication algorithm is successfully verified by the simulation. And for ensuring this some intentionally created error situations are also verified. The results are shown below.

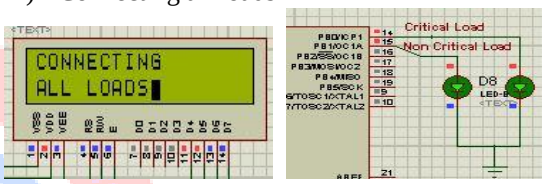
i) Disconnecting all loads



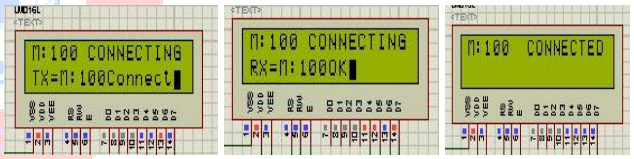
ii) Connecting critical loads



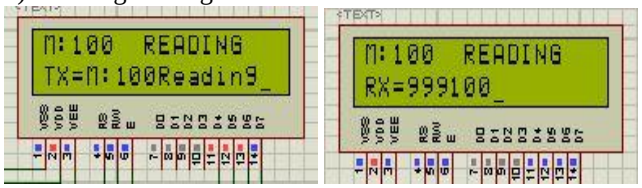
iii) Connecting all loads



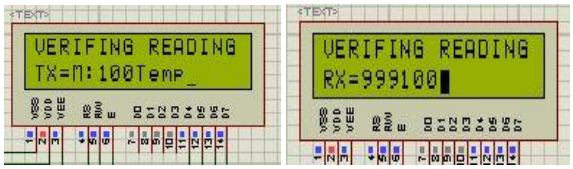
iv) Connecting to meter100



v) Taking reading from meter100

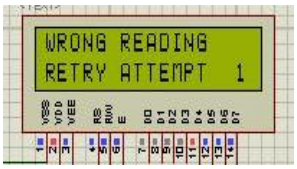


vi) Verifying reading



vii) When readings match

viii) When reading mismatch occurs and 3rd try fails



ix) When meter doesn't work and 3rd attempt fails

VI. CONCLUSION

High processing speed can be achieved by using ATmega 8 for manipulating and displaying data. Simulation results of Power Line Communication protocol is error free. And the system is cost effective also. Hence the proposed system is highly efficient. Since the distribution system is divided into critical and non-critical loads ,it is more intelligent.

VII. FUTURE WORKS

The same system can be modified to implement water supply monitoring and gas monitoring systems without any significant change in the hardware. To improve the efficiency of the system software can be installed in personal computer.

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