Smart Energy Meter and Data Logger

Anadi Shankar Jha, Anish Agrawal, Mohammad Rizwan

Abstract:*The paper is aimed at discussing the coming technological trends in smart energy monitoring and tracking and to suggest any possible improvements in the same. The paper showcases an economical Rasbery Pi based model for smart energy metering and automatic data logging. The system under study uses a PQ analyzer for data monitoring, DHT22, pyranometer sensors for data acquisition. The various communication protocols for data transfer like Modbus, I2C, RS485 are studied with regard to the system. The sample size of data is from a 5kW, 302.2 V solar panel system. A three-phase solar inverter provides the electrical power output. A Meco solar analyzer present at University lab has been used to log electrical data. A major drawback of the same is its inability to measure data while the panels are connected to a load. Thus, a smart energy meter that constantly monitors electrical data as well as ambient environmental conditions has been implemented with the help of raspberry pi. Data such as irradiance, temperature, voltage and current are taken. Data is automatically logged into a SQL database.*

The aim of this paper is to study the current technological trends and propose possible areas of improvement in the current technology.

Keywords:*Smart meters, Solar panels, Solar irradiance, MPPT, P/O algorithm, Modbus Protocol, I 2 C Protocol, RS485, Automatic data logger system, Sensors, PQ Analyzer*

I. INTRODUCTION

This With the increasing demand of renewable energy and their integration in the present grid there is an urgent need of a robust smart metring system which not only providing monitoring of data but also has an in-built data logger system which stores data for later analysis.

The system described in this paper is a low cost smart solar energy meter and data logger system. The system is designed to monitor data coming from a 5kW, 302.2 V solar panel system. The system measures data like temperature, humidity and irradiance via sensors like DHT22, BH1750FVI which is sent to a PQ analyser for data monitoring. This data is then sent via various communication protocols like Modbus, I2C, RS485 and is later logged into a SQL database.

The data sample here is sampled at an interval of 10 seconds. It is simultaneously located to a SQL database and periodically published on the internet. It is also logged in the microSD card of the Raspberry Pi.

Rupert Gouws et. al. [2] presents a hardware module for logging consumed power from a smart power meter and storing it on external storage. The logged data is transferred to an android application where it is displayed visually on the graphs. Ikbal Ali et. al. [3] highlights the importance of solar rooftop panels for energy generation for grid tied systems. The paper shows the method of bidirectional energy flow with the help of smart meters. It gives the importance of information exchange via communication protocols like IEC 61850 and other functionalities like power flow control.

Thomas Waas et. al. [4] analyses the latency, needed bandwidth, and scalability for collecting data on the Modbus TCP/IP protocol. The analysis results show that the solution with Modbus is scalable. K. Jamuna et. al. [5] proposes a design of a low-cost smart metering solution based on the choice of open electronics and protocols which will likely enable the adoption of a reasonable number of meters.

A. Gaga et. al. [6] gives the description of maximum power point tracking where a DC-DC boost converter is used for impedance matching between solar panel and load. The MPPT algorithm discussed in detail is the P/O (Perturb and Observe) algorithm. A.C.D. Bonganay et. al. [7] discusses the recent trends of communication in smart metering. The paper shows the integration of Modbus protocol in Raspberry Pi and subsequent data logging to a My SQL database.

G. Prakash et. al. [8] presents the modelling of the solar PV array and implementation of perturb and observe algorithm for maximum power point tracking.

II. PROPOSED SYSTEM

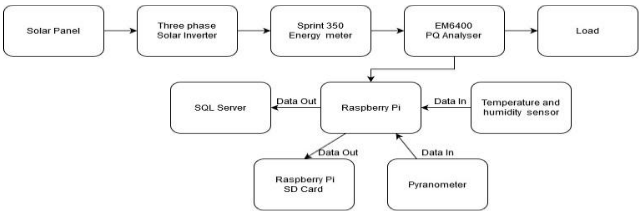

Figure 1: Proposed System

A. Hardware

Solar Panels: Two strings of 10 solar panels, each of 250 kW are connected in parallel to provide a total power of 5 kW at a maximum of 307.2 V and 16.3 Amp DC. Photon PM0250 solar panels are present in the proposed setup.

Manuscript received on February 10, 2020.
Revised Manuscript received on February 20, 2020.
Manuscript published on March 30, 2020.
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Solar Inverter: A luminous 10 kW on grid solar inverter converts the DC power output of the solar panels to three-phase ac power at 50 Hz **which** is then provided to the load. It is capable of quickly disconnecting from the grid in case of utility failure. As the load is connected to both grid as well as solar power, it is required for power switching.

Energy meter: Sprint 350 is a metering solution for three-phase direct-connected system installations. It is a highly accurate meter and can be used for residential as well as commercial applications. It is connected in a 3-phase 4-wiring configuration. The voltage range of this meter is 230 V phase or 415 V line. It has a current range of 5-30 A, 10-40 A, 10-60 A and 20-100 A. This meter works at mains frequency of 50 Hz ± 5%. In this system it is providing input to the EM6400NG PQ analyzer.

Power quality analyzer: A Schneider Electric EM6400NG PQ analyzer provides three phase energy data like phase voltages, line voltages, harmonics, power factor etc. to the Raspberry Pi which logs the data with sensor data to the SQL database. The EM6400NG uses Modbus RTU serial communication to send and receive data.

Raspberry Pi: The Raspberry Pi 3 is a multipurpose miniature computer board. A Pi 3 is being used in this project due to its versatility, ease of configuration and its networking capabilities that other microprocessor-based systems don't have. The Pi 3 offers 40 GPIO pin inputs along with 4 USB ports for data input and output. In this setup a custom python script is uploaded on the Raspberry Pi and it works as the brain of the smart meter.

Temperature sensor: The DHT22 sensor is a relatively inexpensive digital temperature and humidity sensor. It uses a capacitive humidity sensor to measure the environmental humidity and a thermistor to measure the temperature of the surrounding air. The output signal is a digital signal on the data pin. It's a highly accurate sensor for measuring temperature and humidity. It is preferred over the other DHT series sensors due to its higher accuracy.

Pyranometer: SR03 pyranometer sensor is used to measure the irradiance to the sun. It has a field of view angle of 180°. It measures hemispherical solar radiation and has a spectrally flat response across the full solar spectrum. It is used to measure the performance of the photovoltaic system.

B. Software

Raspbian is a LINUX based 32-bit operating system which acts as an operating system for the development board. It is capable of running all the programs required by the smart meter. Python 3.7.2 has been loaded on to this OS which runs the custom script for the smart meter. SQL language has also been added to this OS for database management functionalities. Oracle Database is the database management system used for logging of data to an online server.

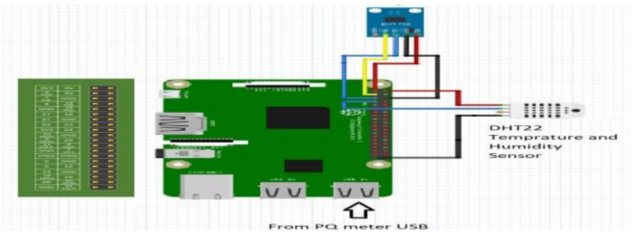

Figure 2: Smart Meter Sensor Setup

III. DATA TRANSFER PROTOCOL

Modbus: It is the communication protocol used in Industries for transferring Operational Data (OD). It supports serial (RTU) and Ethernet communications (TCP/IP). It works based on Client-Server architecture, where the device acting as Server is called as 'Master' and Client as 'Slave'. Modbus Slave transfers data, when it receives request from Modbus Master.

The Modbus RTU message consists of the address of the SlaveID device, the function code, the special data, depending on the function code and the CRC of the checksum. The cyclic redundancy check (CRC) consists of two bytes added to the end of every MODBUS message for error check

Table 1: Modbus data transfer format

SlaveId	Function Code	Special Data	CRC

Modbus Protocol in this project is being called via MinimalModbus API for Python. The PQ meter, EM6400NG uses MODBUS RTU format for storage and transfer of data. The register address, list, data type along with data to be measured are mentioned in the below given table. Three data formats, INT16U, FLOAT 32 and 4Q_FP_PF are being used in our application.

The registers used here are as given in the table

Table 2: EM6400 Modbus registers

Description	Register	Units	Size (INT16)	Data Type
Year	1845	---	1	INT16U
Month & Day	1846	---	1	INT16U
Hour & Minute	1847	---	1	INT16U
Current A	3000	A	2	FLOAT32
Current B	3002	A	2	FLOAT32
Current C	3004	A	2	FLOAT32
Voltage A-B	3020	V	2	FLOAT32
Voltage B-C	3022	V	2	FLOAT32
Voltage C-A	3024	V	2	FLOAT32
Voltage A-N	3028	V	2	FLOAT32
Voltage B-N	3030	V	2	FLOAT32
Voltage C-N	3032	V	2	FLOAT32
Active Power Total	3060	kW	2	FLOAT32
Reactive Power Total	3068	kVAR	2	FLOAT32
Apparent Power Total	3076	kVA	2	FLOAT32
Power Factor Total	3084	---	2	4Q_FP_PF
Frequency	3110	Hz	2	FLOAT32

Retrieval Number: F7971038620/2020©BEIESP
DOI:10.35940/ijrte.F7971.038620
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
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I2C: It is a serial protocol for two-wire interface to connect low-speed devices like microcontrollers, EEPROMs, A/D and D/A converters, I/O interfaces and other similar peripherals in embedded systems.

RS-485: It also known as TIA-485(-A), EIA-485, is a standard defining the electrical characteristics of drivers and receivers for use in serial communications systems. RS485 can have multiple Commanding Devices and multiple Listening. For example, you can connect one PC (the Commanding device) to 10 temperature controllers (listeners).

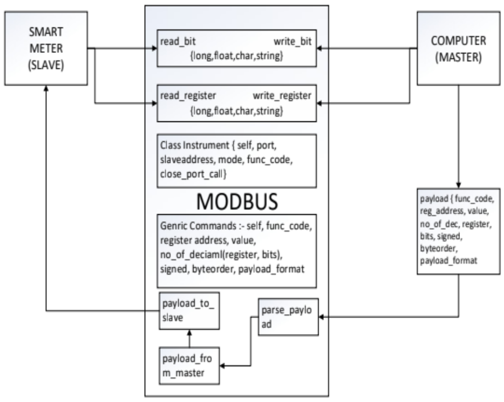

Figure 3: Modbus Data flow diagram

IV. ALGORITHM

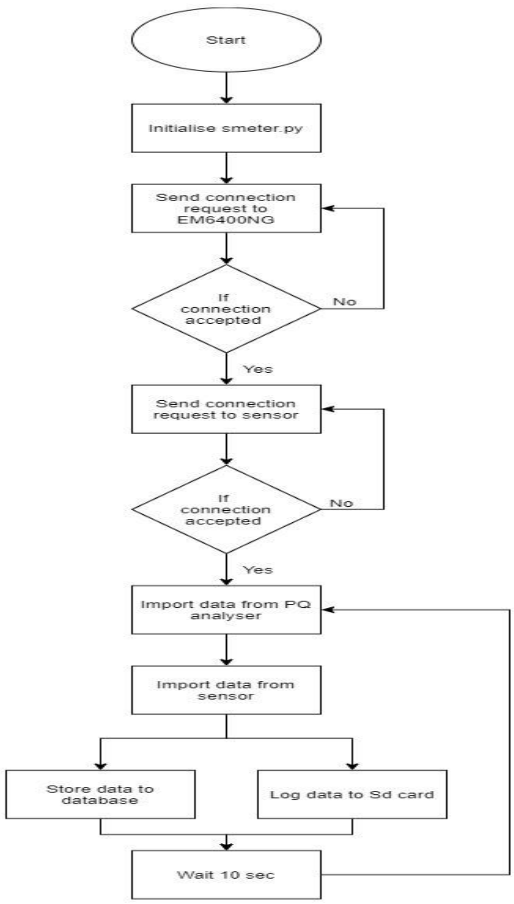

Figure 4: Flowchart for algorithm

V. RESULT AND DISCUSSION

The hand held Meco analyser was used to measure the daily power curve of the string of solar panels. The following result was obtained as given in figure 5.

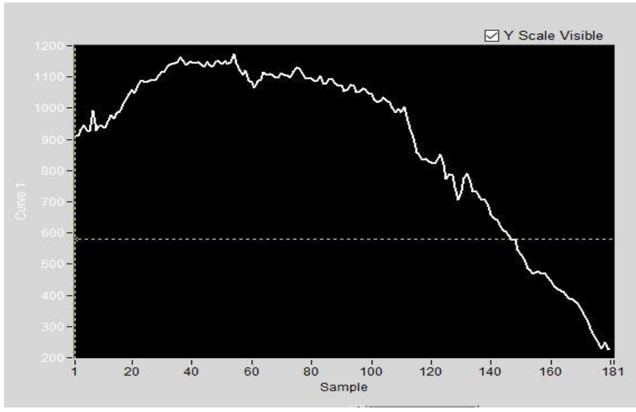

Figure 5: Meco Solar Analyzer Data

Figure 6 represents the power and irradiance curve which has been obtained via the solar smart energy meter setup described in this paper. The Figure 5 and Figure 6 have a nearly similar characteristics as they should have.

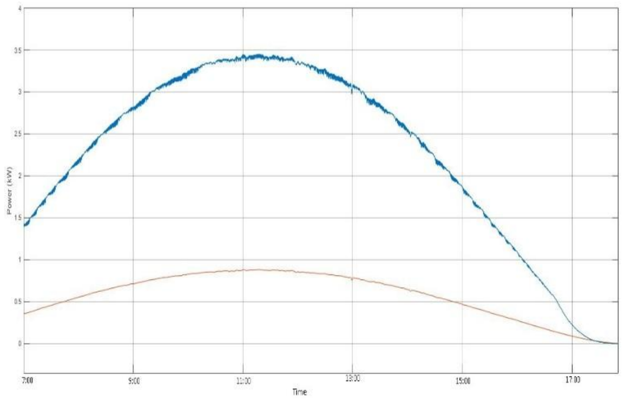

Figure 6: Smart Meter Data

The connected setup of the smart energy meter is as shown in the Figure 7.

Figure 7: Smart Meter Connections

VI. CONCLUSION

The Data logger system has successfully been implemented. It is currently collecting data at a time stamp of 10 seconds over a time span of 7 a.m. to 7 p.m. everyday. The data is logged to the SQL database automatically in real time.

Through this we have removed the necessity of manually logging the data. For further analysis and to do a detailed study on the generation side, more data samples are currently being collected via this system.

FUTURE SCOPE

Based on our current study and proposed design of hardware model there is still scope of including a predictive analysis system on the generation side. Various MPPT algorithms like P/O can be implemented in the current system on the generation side.
The generation can be predicted using various algorithms like fuzzy algorithm, Genetic Algorithm etc.

ACKNOWLEDGMENT

We would like to thank the Head of Department of Electrical Engineering, Delhi Technological University, Prof. Uma Nangia for making this research possible and for giving us support and guidance.

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