Energy Management System for Analysis and Reporting in the Advanced Metering

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Abstract. A smart meter is a device which is used to collect the consumption demand data from home appliances. Energy Management System for analysis and reporting is data communication based software that received encrypted data from electronic energy meter reading Instrument and electronic energy meter. It displays data in user readable format after some required conversion. This paper presented an overview of Advance metering infrastructure and Energy management system. Later, described the security and functionality of the Energy management system. After that it shows the different report obtained by the Energy managements system which includes six months of Billing History, Tamper details, Load Survey up to sixty days and more according to user requirement using Crystal report. Load survey data are represented in tabular and graphical format. User can view all, daily, monthly and many more presentation format.

Keywords: Smart grid · Security · Advanced Meter Reading (AMR)
Head End System (HES) · Energy Management System (EMS)
Advanced Metering Infrastructure (AMI)

1 Introduction

Smart meter is an advanced energy meter that measures the energy consumption of a consumer and display on demand data that provides added information to the utility company compared to a regular energy meter [1]. The user is able to see the daily weekly and monthly consumption by means of display installed at home [14]. It is possible to manage the power consumption for energy optimization purposes, both in terms of costs for the customer and energy saving in this way [2]. Here, Fig. 1 represents the advanced metering infrastructure (AMI) extending Advance meter reading (AMR) mechanism by enabling duplex communication between the meters that permits instructions to be sent from utility datacenter to other meters for various purpose that includes Billing information, pricing information, time of delay, load forecasting,

Demand side Management/Demand-Response actions, or remote service disconnects, load forecasting and outage management [10].
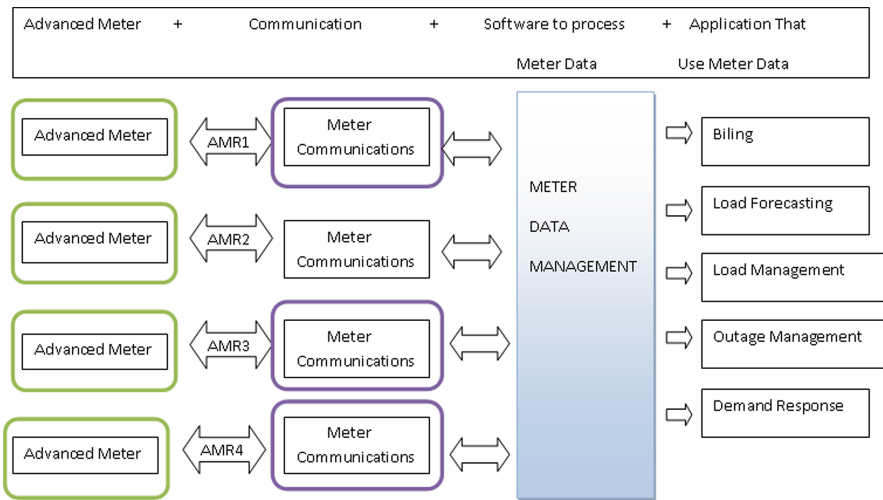

Fig. 1. Advanced metering infrastructure block diagram (conventional)

In order to analyze and view the data of energy electric meter, author has proposed Energy management system for reporting and analysis of that data. Energy management system is capable of presenting different category of data like Power factors, Tariff energy, Voltage Phase data etc. To view and analyze the electric meter data for single meter or group of meters, for reading the data collected now or past, the energy management system has well featured Graphical user interface (GUI). It also has Data analysis and presentation tool that presents various set of data such as Tamper record, billing records, cumulative energies, History Data, Maximum demand and Instantaneous value. Data is collected from the energy meter using International Electro-Technical Commission (IEC) protocol (62056-46) [4]. Data presented in the form of reports like general report, Instant report, and main energy Consumption reports etc. This Energy Management system is also used for generation of bill by the third party on the basis of billing section parameters which includes Cumulative energy, Load factors, voltage imbalance etc.

2 An Overview of Advanced Metering Infrastructure (AMI) and Energy Management System for Analysis (EMS)

Advanced metering infrastructure consist of advanced meters or smart meters that monitor the various factors like power usage, communicate and control to optimize the energy usage, implement data management systems to store and process metering and

control data [3]. The major functionality of Advanced metering infrastructure (AMI) include Energy Audits and Accounting, Demand Response or Demand Side Management, Quick communication of abnormality alarms, prepaid and postpaid model for Green energy into a grid for efficient billing cycle [9]. Meter must support a common communication protocol that connects with head end system (HES) [16]. To get this functionality a robust system and duplex communication between devices is required [13, 15].

The Extended advanced metering Infrastructure have 3 basic components:

- DLMS compliant (Device Language Messaging Service) meters that exchanges and uses data with fast communication port (Minimum of 9.6 kbps) connect/disconnect contactors and an optional load control switch [17].
- Modems and duplex communication network for connection between meters and the HES (Head End System) [12]. This communication take place by using the standard Interfaces as shown in Fig. 2 [18].
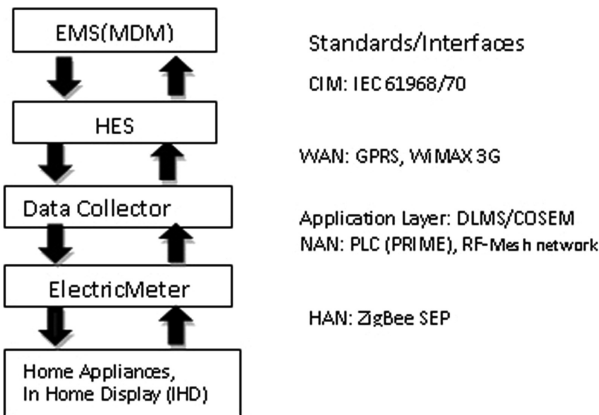

Fig. 2. Advanced metering infrastructure system interface

- Head End System (HES) and Meter Data Management (MDM) scheduling, Software Data collecting, setting threshold values and meter configuration are the key functions performed by head end system. Head end interface system is directly connected to various types of meters via collector or directly with meters attached modem [5, 6].

Energy Management system for analysis and reporting is meter data management (MDM) software. The Energy Management System supports set of data from smart meter and digital meter of various types with minor changes, so that data is uploaded in proper format and path of energy Management System without any manual intervention once the menu is selected. It supports local readout directly from meter through optical interface.

3 Energy Management System Security and Architecture

3.1 Energy Management System for Analysis and Reporting Security

Energy management system for analysis and reporting first received encrypted data from electronic energy meter. The transfer of data must be fraud proof and highly reliable [11]. The EMS (Energy Management System) software shall have a data analysis module, which shall import the data collected from these meters. The entire data stored in the EMS shall be encrypted [8] on the basis of various encryption technique. The Energy Management System that secures the system throughout all the operation is the unique feature of proposed Energy Management System [19]. The security of the system will be maintained on the basis of password and registration key check during the application startup. The system's security is maintained by registration key and password while starting application, generated files will be in encrypted and retained in non-readable format.

3.2 Energy Management System for Analysis and Reporting Architecture

Modified architecture of Energy Management system (EMS) fetch the data from an electric energy meter, after that Energy Management System for analysis and reporting generate raw data, when there is communication with meter. SLG (Encrypted, Protected Data/log File) file is generated and it contains all the details of electric meter raw data. This raw data is uploaded into database and from database user collect the information of meter (Fig. 3).
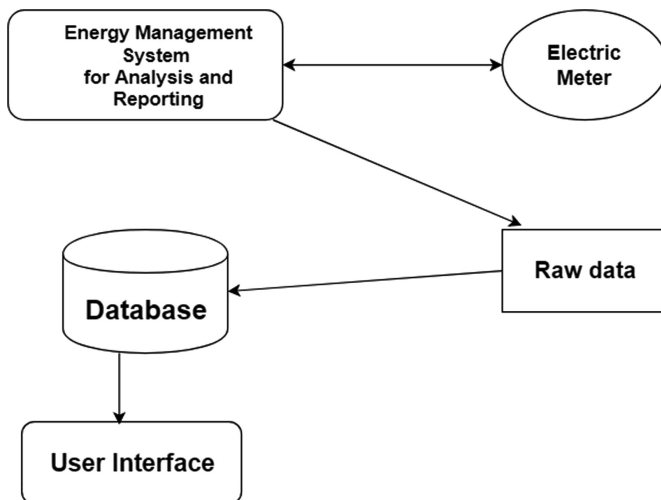

Fig. 3. Energy management system for analysis and reporting architecture

The programming architecture of Energy management system for analysis and reporting will follow 3-layered architecture application layer, presentation layer, business layer and data layer.

- In application layer where forms is design using the controls like textbox, labels, command buttons etc. and the presentation layer is controlled by resource file manager. All the label captions are displayed according to the values in the resource file.
- In business layer is the class where the functions which get the validate various data from the application layer and passes through the data access layer. All validations are kept in this layer. Validation is performed according to the rules defined in external validation file.
- In Data layer the class which gets the data from the business layer and sends it to the database or vice-versa. This layer only interacts with the database. We write the database queries or use stored procedures to access the data from the database or to perform any operation to the database (Fig. 4).
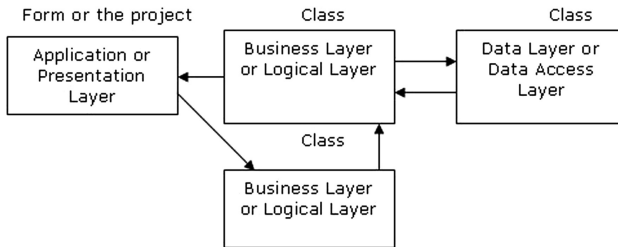

Fig. 4. Energy management system summary of design

4 Functional Requirement of Energy Management System for Analysis and Reporting

Energy Management System is software for data collection and reporting from energy meters. It is designed to collect, organize and present meter data for effective data management. This system is used to collect data from meter. Quality of service such as correctness, response time, reliability etc. function should provide correct result and response time of communication should be low. The Energy Management System development platform should be such that it can easily accommodate in future various meters types and protocols of IEC based meters [22]. Meter data presentation in tabular and graphical formats. Multilevel user management Scheduler for automatic meter reading Consumer & meter data storage Exhaustive online help Easy installation [7].

In Energy management system for analysis and reporting all the information about abnormality events shall be accompanied with date and time stamping [19]. This information is displayed in the sequence in which it happened. The screen visible to user on error will include Exception Number, Exception Summary and the error log

will contain Exception Details (exception stack trace) Date-time stamp and all errors will be logged so no unhandled exceptions thrown by the system [20] (Table 1).

Table 1. Energy management system for analysis and reporting function

Functional requirement	Main functions
License and user management	License key to take care of the security of the application and consumer data management
EMS definition	EMS definition on the basis of active meters consumers etc.
Data acquisition and configurations	Retrieve meter data and settings by direct communication from Meter and set COM port setting and serial port communication
Authenticated billing code (ABC) and temper detection	ABC used to transfer bills, other meter information and used to detect tempers
Reports	EMS facilitates user to view and print the selected type of data report

4.1 User Group

Energy Management System user group is divided into user management, change password, application login details and logoff. User management interface is used to add, view and edit user's detail. Change Password is used to change the password of the EMS (Energy Management system). Application login details help in adding more security to the system and through which users identify the user login time and its identity.

4.2 Energy Management System Definition

Energy Management System definition through we identified Area definition, Group definition, Active meter, Inactive meters and free consumers.

4.3 Configurations

Users can set COM port (communication port) setting and Serial Port communication setting like Baud rate, Bit Rate, Parity, and Stop Bit according to need.

4.4 Authenticated Billing Code

It is a unique and innovative feature to transfer meter status and other billing data to utility in secure or encrypted form.

4.5 Tamper Detection

Separate Records are kept for tampers in meter. Multiple folders are designated to collect record data from folders, these folders are called as compartment. Sometimes

some changes are made in energy meters such that it registered less energy than actually consumed. The Energy Management system is designed to detect all the tempers, its type and instantaneous parameters when temper event has occurred.

5 Advantages of Energy Management System for Analysis and Reporting

5.1 Reliability

All errors are logged in Proposed Energy Management System. There would be no unhandled exceptions thrown by the system. Proper messages will be shown to the user if any error occurs and the application should never exit or crash in any case.

5.2 Security

Inputs are validated and critical log activity is maintained. The log will have the information of user who involve in the operation, operation detail, date-time stamp.

5.3 Maintainability

Energy Management system (EMS) supports the future changes which includes bug fixing new application addition and addition of any other requirement which is needed at later stage.

5.4 Data Rate

Data rate is related to related with how fast the data is communicated between Energy management system and Head End System (HES) [21]. Proposed Energy Management system provide Minimum data rate 10 kbps.

6 Report and Results

EMS (Energy Management system) for analysis and reporting helps user to view, analyze and print the different report of data which include detailed report, meter wise report, date wise report and group wise report. The data is stored in tabular form of corresponding databases which can be identified by meter number. Data parsing modules and meter data collection carries meter data. Reports is divided into three Sections.

1. *General Section*
   Which includes meter data analysis report, instant report, general report and transaction log. For example, Meter data analysis report further includes general details and instantaneous details etc (Fig. 5).

Meter Data Analysis Report

Meter ID	: 0000081	Location	: ---
Consumer ID	: ---	Region	: ---
Consumer Name	: ---	Division	: ---
Installation Date	: ---	Circle	: ---
Meter Voltage Rating	: ---	Contract Demand(kW)	: ---
Meter Current Rating	: ---	Active Meter	: No

General Details

Description	Value
Meter ID	0000081
Meter DateTime	14/02/2013 12:33
Reading DateTime	14/02/2013 12:31:47
PC Dump DateTime	14/02/2013 13:40:57
Firmware Version	10.19X
Manufacturing Date & Time	00/00/0000 00:00
Meter Rating	00V, 00-00 A
Accuracy Class	1
Meter Constant (Impulse/kWh)	3200

Instantaneous Details

Description	Value
Voltage (V)	244.91
Phase Current (A)	00.00
Neutral Current (A)	00.00
Phase Power (kW)	00.00
Neutral Power (kW)	00.00
Power Factor	+0.00
Present Month Average PF	0.13

Fig. 5. General section meter data analysis report

2. **Billing Section** of reports is on the basis of Main energy, Main energy consumption, Maximum demand, Billing load factor, Billing Average PF details (Fig. 6).

Billing Average PF Details

History	Average Power Factor
01	0.80
02	0.75
03	0.74
04	0.74
05	0.78
06	0.00
07	0.00
08	0.00
09	0.00
10	0.00
11	0.00
12	0.00

Billing Load Factor

History	Billing Load Factor
01	00.81
02	00.70
03	00.81
04	00.63
05	00.80
06	00.00
07	00.00
08	00.00
09	00.00
10	00.00
11	00.00
12	00.00

Fig. 6. Billing section meter data analysis report

3. **Other section** of reports contains tamper event history details, load survey, daily survey. Other section is useful for detecting at what time which type of tamper is occur (Fig. 7).

Fig. 7. Other section meter data analysis report

7   Conclusion

Energy Management System for analysis and reporting software is windows based user friendly system software. The Energy Management System can easily accommodate with various meters types in future. It supports local data readout directly from meter. The Data transfer shall be highly reliable and fraud proof. Energy management system software shall provide all details adequate for analysis and abnormal event data. The software shall have the facility to convert all the consolidated information data of all parameters into ASCII format. The information about meter reading date, billing readings, energy and its maximum demand is be presented in such a way that a user should easily understand.

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