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LATEST FUNCTIONALITY REQUIREMENTS OF STATIC ENERGY METERS FOR AMI

Gyan Prakash Nirmal, Deepa J. Warudkar, B.A.Sawale
Engineering Officer-1, Engineering Officer-4, Additional Director
Affiliatedt o CentralPowerResearchInstitute(CPRI)Bhopal

***Abstract*-Energy meters are the key component of the Automatic Metering Infrastructure (AMI) and efficient measurement of electricity, interoperability, interchangeable, collection of Energy meter data, smart grid data and strengthen cyber security are the required features of the Energy Meters.**
To verify the compliance of these functionalities of the Energy Meters Indian/InternationalStandards have been introduced.
This Paper shares the latest functionalities requirements of static meters in view of smart grid and AMI also focus on series of Indian Companion Specification (ICS)i.e. IS 15959 (Part1):2011, IS15959(Part2):2016 and IS15959(Part3):2017 which specify operational capabilities of Data Exchange for Electricity Meter Reading,Tariff and Load control which are the key features of the Smart Grid.
Keywords *– Smart Energy Meters, DLMS/COSEM, Smart Prepaid Energy meters, load switch, two way communication, Communicability*

I. INTRODUCTION

The present situation of the world calls for sustainable and efficient electricity generation and its appropriate management method as we aretotally dependent for supply the energy demand onnon-renewable sources, which takes many of years to replenish and it isn't sustainable in the long run[12]. The way out are the uses of renewable energy, Government of India also focusing on the sustainable energy through naturally available energy resourcessuch as hydroelectricity, biomass, geothermal, wind, wave, tidal and solar energies.Results indevelopment of micro grid and Nano grid, which requires efficient Management of supply and demand of electricity, improved interoperability, collection of Energy meter data, smart grid data and strengthen cybersecurity.

Advanced metering infrastructure (AMI) is a joined system of smart meters for capturing data, communications networks for transferring the data and data management systems for efficient use of data collected. With these systems and provision of two-way communication between utilities and customers, the AMI provides several important functions that were not possible previously or performed manually, such as the capability to measure electricity uses automatically and remotely, disconnect and connect service, tamper detection, identifying the abnormal conditions and isolate it and monitor various parameters such as voltage, current, Power factors and harmonics. With customer technologies, such as programmable communicating thermostats and in-home displays, AMI enables utilities for offering time-based tariff and incentives which encourage customers to reduce its demand during peak hours and get the benefit of less tariff rate by managing their energy consumption. [10]

Advance metering infrastructure (AMI) is classified intofour layers:

Top layer is known as the master station consisting of measure data management unit, communication management unit and power user management unit of AMI system. The master station includes the network equipment, servers and various management terminals.

The second layer provide cannels to released communication from the master station to smart meters and smart hand- held terminals and provided channels for power company and users to realized two –way interaction.

The Third Layer is smart measurement and distributed power station, including smart meters, smart hand- held terminals, distributed power generation systems. Smart

meter is a core equipment mainly realize energy metering, parameters measurement, prepaid functions parameters setting, detection of events and reporting, data acquisition and storage, communication, programming, electricity pricing etc.

Fourth Layer is indoor intelligent terminal i.e. Hand Held Unit (HHU) and Smart meter constitute the interactive portal for users. Smart display terminals can read, report and display the energy consumption of electricity, it can report the information of fault and maintenance, announcements issued by the master station can be received and can be seen by electric users and company.

II.METER FUNTIONALITIES REQUIRED FOR THE AMI

Meter being an intelligent component between distribution and consumption of electricity and of AMI, many task to be performed by it as shown in the Figure.1

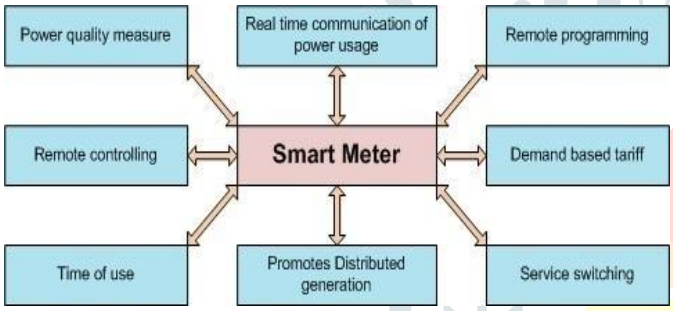

Figure1- Functions of Smart meter in AMI

To perform all the functions mentioned in the above figure, Energy meters have different features. These features of the Energy meter described Table 1 with reference to the Indian standards to confirm its performance.

Table. 1–Static meter functions and its Testing standards

Sl. No.	Type of meters	Functions	Standards
A.	Static Energy Meters, Prepaid Energy Meters and Smart meters	Metrological function	IS 13779, IS 14697, IS 15884, IS 16444 (part 1) and (part 2)
B.	Prepaid Energy Meters and Smart meters	Load switching	IS 15884
C.	Static Energy Meters, Prepaid Energy Meters and Smart meters	Data exchange protocol and Communication	IS 15959 (part 1), IS 15959 (part 2) for Direct Current meters and IS15959 (part 3) for transformer operated meters.

A. Metrological Testing:There are around 40 nos. of tests to verify the performance of the meters at different service conditions such as electromagnetic fields, climatic conditions, under various influence quantities such as voltage variation, frequency variation, harmonics, magnetic fields etc. and also under fault condition such as short circuits and earth faults, which may affect at the fields.

B. Load switching capability: Smart meters roll out is due to its functionality to manage supply through the reduction of demand during peak hour, individual loads switching for energy saving, prepaid billing for the consumers and user refusing to pay electric bill or abusing the use of electricity can be disconnected by the utility. This ability to disconnection/connectionof power is possible because of the use of latching relays (Load Switch) inside the meter and hence the quality, reliability and safety of the latching relays are an important aspect. There are tests stated in the standards IS 15888 to verify the load switch [1].

C. Data Exchange Protocol: The main intention of introducing Meter protocol testing is to ensure interoperability of Energy Meters of various manufacturers for utilities and to support of AMI (Automatic Meter infrastructure).DLMS (Device Language Message Specification) is important for achieving interoperability and hence changed the Power sector from monopoly to open and standardized market.'Tests for Data Exchange Protocol' carried out for data verification on optical port to verify the association requirements, parameters and profiles in accordance with the standard. The 'Tests for Smart Meter Communicability and Functional requirements' carried out on meter for Compliance to DLMS/ COSEM (companion

specification for energy metering) open protocol.

III. CATEGORIES OF STATIC METERS

Static Meters are divided in deferent categories depending upon the energy load requirements and type of consumer such as Domestic consumers, industrial consumers and measurement of energy for utility. The electricity meters have been selected for compiling comprehensive lists of parameters with theirdata identifiers in the following categories as required for data networks in India for COSEM procedures and services[2][3][4].

Table. 2 – Categories of Static meters

Sl.No.	Service category	Metering Nomenclature/purpose
i	A	This category is for use at Distribution Transformer Centers and sub-station feeders. The parameters listed for this category is forEnergy Accounting and Audit purposes
ii	B	Thiscategory of meters use at meter banks and network boundaries. The parameters listed in this category is for import/export of energy. Availability based tariff(ABT) regimes also included in the category
iii	C	This meter is identified for use at 3 phase 4 wires Whole current / direct connected meter, Single phase whole current meter. The parameters listed for this category is for consumers who draw energy from the grid.
	C1	Transformer (LTCT/HT-PTCT) operated meters
	C2	Three Phase Whole current/direct connected meters
	C3	Single phase Whole current meters
iv	D	Smart Meter meters with two way communication
	D1	Single phase Whole current Smart meters
	D2	Three Phase Whole current/direct connected Smart meters
	D3	Transformer (LTCT/HT-PTCT) operated Smart meters

IV.IMPORTANCE OF DLMS/COSEM IN ENRGY METERING

In contrast to other types of equipment, testing of energy meters for communication protocol is crucial to ensuring that the meter complies with the Meter protocol standards as stated in Table 1 and also in order to make the device work vendor-neutrally, interoperability and the simple collecting of data from the meters using any third-party client tool or utility specified tools.

The Open Systems Interconnection (OSI) model is used by DLMS/COSEM to simulate information exchange between meters and data gathering systems i.e. Head end System (HES) of the utilities.

The Open Systems Interconnection (OSI) consisting of functional layers for communication process arrange one above other as shown in Figure 2 and each layers have different responsibilities. [9]

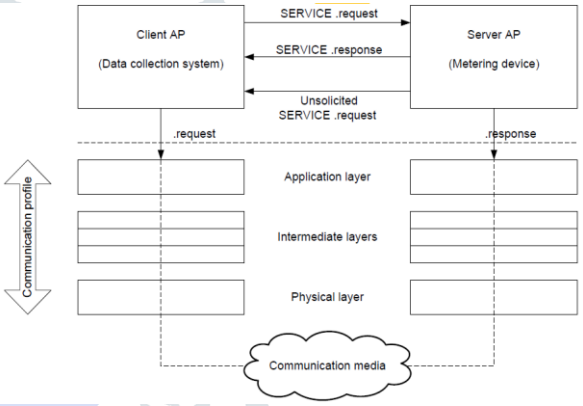

Figure2– Layers of OSI

The features of the Energy Meter – interoperability, Remote data collection, two way communication (Read and write) and connect-disconnect are the requirement of the AMI. Verification of these features is described below.

V. COMPLIANCE TESTING AS PER IS 15959: 2011(PART 1),IS 15959: 2016(PART 2)and IS 15959: 2017 (PART 2) INDIAN COMPANION SPECIFICATION

The main aim of conformance testing is to verify that meter under test (MUT) conforms to the requirement of standard. It is also used to achieve interoperability among various make of meter.
The testing procedure contains two elements:

- Conformance to DLMS/COSEM (IEC62056) Protocol Requirements
- Parameter Verification as per standard

These tests are carried out in order to verify that all mandatory objects, data types, application association, profile parameters, programmable parameters and event profiles are implemented as per standard requirements. DLMS/COSEM (IEC62056) Protocol Testing requires Phantom source to energize the Meter as per required

testing parameters and Testing Tools as shown in Figure 3.

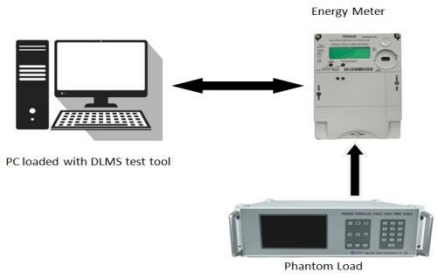

Figure3– Test Setup for DLMS/COSEM Testing

1. Conformance to DLMS/COSEM (IEC62056) Protocol Requirements

It is a well-planned and standardized process of evaluation of an Energy meter about its all implementation of DLMS protocol. The objective of this test is also to verify the implementation of declared feature of standards (IS15959& IEC62056) and DLMS Yellow Book.

The DLMS conformance process contains four elements:

i. The conformance test tool (CTT tool) that is a computer program that implements different tests on MUT.
ii. Conformance test information file (CTI File) that is a plain text file that contains information necessary for selecting and performing tests on MUT.
iii. The Conformance test plans that are tests that performed on MUT.
iv. The conformance test report that contains the information of outcomes of the entire test that performed on the MUT.

i) The Conformance Test Tool(CTT Tool):

It is a computer program that implements different tests on MUT. Computer program act as client and MUT act as DLMS/COSEM server. The tool sends messages to MUT and observes the response received.

CTT can perform following on the MUT

- Selection of communication parameters
- Selection of Test options and test cases to be performed
- Running the test sessions
- Generation and saving of test results

CTT has different version that used for testing

- CTT 3.0 has been introduced in July 2015 and used until 31st December 2019
- CTT 3.1 has been introduced in March 2017
- DTT 4.1 & 4.2 had introduced recently and is the latest version of the tool available.

ii) Conformance test information file (CTI File):

CTI file is plain text file that contains information necessary for selecting and performing test cases.
CTI files contains information related to meter manufacturer including its FLAG id, meter type, sl. no, logical name, application association and COSEM interface object.

iii) Conformance Test Plans:

The conformance test plans contains many test cases that performed on MUT during conformance testing. Each test plan is executed in order to verify specific requirement.
Some of the test plans that are executed on MUT are as follows:

- HDLC based data link layer test
- DLMS/COSEM application Layer
- Secure Message Exchange
- General Block Transfer
- COSEM Object
- Transfer of Symmetric Keys
- Public Key Certificates
- Security Policy

These tests are designed to verify specific ability of MUT, for example setting meter into NRM(Normal Response Mode) and NDM(Normal Disconnect Mode), inactive & inter frame timeout are verified in HDLC based tests, all COSEM object present in the MUT are verified in COSEM object test case. There are test cases which applicable to some specific IC's like data protection, profile generic, Push and security setup. Test related to symmetric key transfer and secure message exchange are also there in the conformance testing.

iv) Conformance Test Report:

Test report is generated after completing the whole testing process. Test report is consisting general test information like date of test, CTT version, manufacturer information, FLAG I'd. Summary of test report mainly contains number of test cases executed, application context supported, authentication mechanism supported,

extended DLMS services and security features supported by MUT.

Test report also contains different outcomes for all test cases performed on MUT, these outcomes are as follows:

PASSED:

It means test outcome conforms to the requirement to the standard.

FAILED:

It means that test outcome does not conformance to the requirement of the standard.

INCONCLUSIVE:

It means test outcome neither pass nor fail (sometimes the verdict of selective access test is inconclusive due to unavailability of data in profile buffer).

INAPLLICABLE:

It means that test cases are not applicable to the MUT as per declared CTI file.

SKIPPED:

It means that test cases are not performed on the MUT.

2. Parameter Verification:

Parameter verification done as per the requirement of Indian standard (IS15959).List of Parameter for different categories of meters already described in Indian standard. In the parameter verification, all the Interface Classes are verified with their all the attributes.

List of parameters that are verified are as follows:

i) Object List Download and association properties

In association properties, all the association with their associated mandatory object and some object related to that association are verified. Sign-on mechanism for all associations are verified e.g. lowest level for PC (Public client), low level for MR (Meter reader) and high level for US (Utility setting) & FW (Firmware).

Services required for all associations are also verified e.g.

PC Association–GET

MR Association-GET, GET with Block Transfer, Selective Access

US Association- GET & SET, ACTION, GET & SET with block transfer, Selective Access etc.

FW Association-ACTION, SET and GET

PUSH Association- Data Notification, General Block Transfer

ii) Security Setup

There are two security schemes present in the Indian standard for metering

a) Basic Security -

The basic security provides sign-on authentication as low level and high level security as applicable to the respective association. Basic security does not provide encryption and authentication of data. All the meters require implement basic security feature.

b) Advance Security -

In advance security, encryption and authentication of data are provided by application programmed and transferred using ciphered APDU's. Smart meter is required to implement advance security.

The confidentiality of meter data is achieved by encryption. 'Logical name with ciphering' application context provide encryption service in the smart meter. Ciphering can be encryption, authentication or both.

iii) Simultaneous Operation

Simultaneous Operation is only applicable to meters that have both Optical and Electrical port, so it is not applicable to the smart meters. Simultaneous operation of both ports is not permitted as per standard. In case if both ports are accessed, optical port shall have priority.

iv) Profile Generic Parameters

The profile generic objectsare classified as follows:

a) Instantaneous Parameter:

These parameters are updated in the meter using their internal sampling and programming and when it read via client the latest value are available to read. All the parameters listed under instantaneous parameter are separate entity, it means any parameter can be read independently. The instantaneous parameters shall be stored as profile parameters using the OBIS code 1.0.94.91.0.255. The attribute 2 of each of the capture objects shall be stored into the profile at the instant of a GET request from the client.

b) Block Load/ Load Survey Parameters

It is an array of energy values that are stored under block load profile. Recording interval for block load is set to either 15 minutes or 30 minutes. This recording interval is called Profile capture period, it can be change using US association and event id_153 generated in the meter.

Block load profile shall store zero value for whole 24 hour when meter is energized even for small period of time in whole day. The OBIS code for block load profile

is 1.0.99.1.0.255 available in the IC 7. The capture objects of this block load profile are given in the standard.

c) Daily Load Profile Parameters

This is an array of load survey data captured as profile parameters daily at 00:00:00. The OBIS code for daily load is 1.0.99.2.0.255 which is also available in the IC 7. The capture objects of daily load profile are given in the standard.

d) Billing Profiles

Billing profile parameters are required for accounting purpose. Billing profile should be generated by the meter at first day of month and it should be stored in the memory. The set of data for last 6 (six) cycles and one current billing shall be stored in the memory. The last billing data can be readable at any time from meters when required.

v) General Purpose Parameter:

General Purpose parameters contain nameplate details, nameplate profiles and programmable parameters.

a) Name Plate Details:

Name Plate Details are list of some number of parameters. Some of these parameters are electrical and some are non-electrical quantities. These parameters are also static that do not change with respect to time. All these parameters are grouped together and termed as 'Name Plate Details'. Name Plate Profiles are also available in the IC 7.

b) Programmable Parameters:

Programmable parameters are basically non-electrical quantities. These parameters are generally configuration of meter related parameter like Demand Integration Period (DIP) and Profile Capture Period (PCP). For configuring these parameters access rights are given as per Utility Setting Association of the meter. These parameters are applicable to all categories of meters.

vi) Event Condition and Event Simulation:

Meter subjected to any abnormal condition or any condition that is not normal operating condition of the meter is called tamper event. All the occurrence and restoration of such events must be stored in the meter. The Meter shall also store some predefined parameters with all such tamper events. The number of events that stored in the meter memory is decided mutually by buyer and seller. Total number of event stored is fixed at 200 as per standard. Any exceptional condition that is used to create fraud/tamper is considered as an Event and stored in an Event code object (OBIS = 0.0.96.11.e.255 IC = 1, values of e from 0 to 6). The smart meter shall store the event with unique identifier called event code. Unique identification code is assigned to all possible occurrence and restoration of events. All the events are further divided in the different group depending upon their nature of occurrence. The different groups of event are as follows:

a) Voltage related events
b) Current related events
c) Power failure related events
d) Transactional events
e) Other events
f) Non rollover events
g) Control events

vii) Selective Access:

Selective access is used to access any profile buffer of the meter selectively without reading full profile. As per Indian standard all energy meter should support two types of selective access:

a) Selective Access by Range:

Selective access by range permits to read a subset of the rows and columns in the Profile buffer. To select any subset of profile is based on the any of the capture objects present in the profiles. Generally Meter Real Time Clock used in most of the cases to perform selective access. As per Indian standard, selective access by range shall be applicable to block load profile and daily load profile.

b) Selective Access by Entry:

Selective Access by Entry used integer values called from value and to value to filter out data from profiles. If meter event profile contains ten entries then one can selectively take first five entries using selective access by entry. As per Indian standard, onlyfiltering as per rows applicable. Indian standard requires selective access by entry for billing data profile and event log profiles.

vii) Remote Firmware Upgrade:

Indian standard required Smart meters to support remote firmware upgrade feature. A specific association is

created for smart meters called firmware. Firmware association shall contains all the requirement that standard mandates. Firmware upgrade in smart meters shall be limited only to the communication firmware.

Firmware upgrade shall use the Image Transfer classes and mechanisms given in IEC62056-6-2andIEC62056-5-3. The smart meter shall contain of the Image Transfer class (IC: 18) as per standard. The firmware upgrade of smart meter is done in two steps.

First step is Image Transfer, in this a new image file (FW file) is transferred to the smart meter.

Second Step in Image Activation (FW Activation), in this step new image file that in transferred earlier in activated. Again, the activation also can be done in two ways immediate activation and Scheduled activation. Immediate activation uses IC 18, firmware activation done immediately in this case. Scheduled activation uses Single Action Schedule of IC22, in this process we can set a date &time when firmware can be activated.

viii) Connect and Disconnect:

The smart meter shall support remote Connect/Disconnect services as well as local disconnect as cl. No. 11ofIS16444. For this purpose it shall use the Disconnect control Object (IC70) as in Table 3.

Table. 3 – Disconnect control Object

Sl. No	Function	Interface Class	OBIS Codes
1	Disconnect control	70 –Disconnect Control	0.0.96.3.10.255

ix) Push Services:

Smart meter have provision for sending data, notifying tamper event to head end system in unsolicited manned i.e. without getting request. This is called PUSH service which is already defined in the

Table 4 - Push services applicable to meter

DLMS/COSEM. These push services are generated by some triggers. These triggers in case of periodic push are meters real time clock, meter push some predefine

Set of data at a specified interval of time. Triggers in case of event push are occurrence time of the event that pushes by meter. The PUSH service is modelled in the smart meter using PUSH service interface class (IC 40). All the push services that are applicable to the smart meter are as per the table 4.

SlNo.	Identified Push Instance	Push Setup Instance(OBIS)	Push Script Table Number	Usage	Triggering Object OBIS and IC
i)	SMtoHES (data)	0.0.25.9.1.255	1	Intended to be used by smart meter to send Data to HES	0.0.15.0.4.255 22(SingleActionSchedule)
ii)	HEStoIHD	0.0.25.9.2.255	2	Intended to be used by smart meter to send the Message received from HEStoIHD	0.0.16.0.1.255 21(Registermonitor)
iii)	IHDtoHES	0.0.25.9.3.255	3	Intended to be used by smart meter to send the message received from IHDtoHES	0.0.16.0.2.255 21(Register monitor)
iv)	SMtoIHD	0.0.25.9.4.255	4	Intended to be used by smart meter to send the Data to IHD	0.0.15.1.4.255 22(SingleActionSchedule)
v)	SMtoHES (event)	0.0.25.9.5.255	5	The script shall be called through an internal Mechanism on occurrence of events. There is No IC class or OBIS associated with this action	Occurrence of event

VI. ADDITIONAL COMPLIANCE TESTING FOR SMART METERS

The smart meter shall support some tests with their communication module (NAN / WAN)
List of tests as given in Table 5 below.

Table 5 – Tests to be carried out with communication module

Sl. No	Name of Test	Description
1	Association Properties	Object List download for all associations of the meter
2	Data Read	Any five parameters from instantaneous parameters
3	Profile Read	Reading Billing Profile Parameters
4	Selective Programmability	Any two parameters from Programmable Parameters
5	Reporting of Event	Event Push and Periodic Push
6	Connect/Disconnect	Remote Connect and Disconnect of Load Switch
7	Firmware Upgrade	Remote firmware upgrade of meters.

VII. COMPLIANCE TESTING AS PER IS16444:

i) Disconnection Mechanism

The load disconnection (Disconnection of all the load switches) in the smart meter shall occur under the following conditions:

- When overcurrent event occurred in the meter for a predefined period of time (Persistent Time).
- When the loading on the meter increases the limit defined in load control limit function.
- When any tamper condition occurs.
- When meter get disconnect command from head end system, and
- When balance exhausted in the meter in case of pre-payment metering

ii) Reconnection Mechanism

If meter load disconnected due to overcurrent or load control limit, the reconnection procedure as follows:

- The meter load switch re-connection shall be decided by meter locally. Meter tries to connect load switch for some predefined interval of time. If the load across meter is within limits meter shall remain in normal connect mode.

- If the load across meter is still more than the preset load limits values, it will lock out and wait for 30 min (lock out period). After this lock out period the meter shall reconnect the load and if the consumption is still above the limit, again whole process is repeated till the meter loading comes under defined loading conditions. All these connection and disconnection mandatorily notified to Head end system.

- In all other disconnection that occurred in the meter except due to overcurrent and load limit value, the reconnection can be done form head end system only. In any case when communication failure occurs with HES, reconnection of load switch can be done using optical port of the meter locally using predefined security for that purpose.

iii) All connection and disconnection of load switch in the smart meter shall be logged into control Events profiles.

iv) Smart Meters shall also respond to any kind of request form HES that comes with specified security.
Some of the request are as:

- On demand meter reading request from HES
- Scheduled meter readings request from HES
- Remote Firmware Upgrade process from HES
- All kinds of Programming request from HES

v) Status of load switch indication for connect & disconnect) shall be available on the Meter LCD Display.

vi)Smart Meter shall detect all Power On and Power Off condition that occurs in the meter and it shall Communicate it to the HES[5][6].

VIII. CONCLUSION:

Energy meters are now Smart enough and intelligent to capture and made available all required data of energy distribution, energy consumption, fraud and tamper details with connect/disconnect facility. It is the role of utilities and consumers to utilize this data efficiently to

achieve the goal of demand side management and to improve the operational efficiency.

Meter data exchange protocol provides details of parameters required to be monitored and action to be taken at various levels with authentications and encryptions. Introducing DLMS protocol in India also ensured interoperability of Energy Meters of various manufacturers with different communication modules.

IX. ACKNOWLEDGEMENT

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XI.AUTHORS

Gyan Prakash Nirmal, completed graduation in Electrical Engineering from MMMUT Gorakhpur. Presently working as a Test Engineer in Energy Meter Testing Lab CPRI, Bhopal and having experience of three and half year in field of testing and certification on energy meters.

Deepa Warudkar, completed graduation in Electrical Engineering from Nagpur University and M.Tech in HEE from MANIT, Bhopal. From last 20 years working as a Test co-ordinator in Energy Meter Testing Laboratory in CPRI, Bhopal.

B. A. Sawale : BE, MTech, MBA, Senior Member IEEE. He is an Additional Director, Unit Head of CPRI Bhopal. He is also Project Incharge and Unit Head of Regional Test Center, CPRI, Nashik. He is also the Chairman of Sectional Committee ET13 of BIS on "Equipment for Electrical Energy measurement and Load control". He is a Member of International Electrotechnical Committee (IEC) -Technical committee TC13 & Working Group 11, 14 and 15, Member of Maintenance Committee under IEC TC 13. He headed Task force under IEC TC 13 for Safety Standard, Member of state tariff advisory committee of MPERC, NABL.