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Enablement of Consumer-Oriented Interoperable Systems With Integration of CIM and Green Button Standards

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***Abstract*—Future grid evolutions promise to promote the interoperability in the consumer domain. CIM (mainly IEC61970 and IEC61968) is an established standard in the industry to enable the interoperable data exchanges at the upstream levels like generation, transmission and distribution, while the Green Button standards (OpenADE, NAESB ESPI, NIST SGIP-PAP 20, PAP10) are the emerging smart grid standards to standardize the information on energy usage, interfaces at the downstream end-consumer level. This paper presents the various modeling issues, and techniques to move toward integrating these standards to enable the interoperable services at the consumer levels. The challenging task is to identify the options to promote the interoperability between the end-consumer and upstream levels for future grid evolutions. This paper begins to address this issue by identifying the requirements like integrating the external services data from the end-consumer oriented third party tools to EMS/DMS, hierarchical tagging of consumers, combined semantics for third party applications, inter-utility migration of consumers/prosumers, and dynamic consumer/prosumer open access interactions. However, this involves extensions and mappings between the existing CIM, and the green button standards. Without affecting much the base packages, it should be either incorporated in the CIM or Green Button standards at the domain modeling as a separate package. A set of new classes and attributes to the existing CIM and the corresponding XML tags for Green Button standards to realize the integration is proposed. The authors' contributions also strengthen the arguments for creating a separate green button profile for the existing upstream standards.**

***Index Terms*—CIM, consumer migration, consumer tagging, green button, NAESB, NIST, SGIP, smart grid.**

I. Nomenclature

ESPI	Energy Services Provider Interface
NAESB	North American Energy Standards Board
AMI	Advanced Metering Infrastructure
CIM	IEC TC57 Common Information Model
ESI	Energy Service Interface
SGIP	Smart Grid Interoperability Panel
PAP	Priority Action Plan
PG&E	Pacific Gas and Electric Company
OpenEI	Open Energy Information
JMS	Java Message Service
EUI	Energy Usage Information
UDDI	Universal Description, Discovery and Integration
DT/HT	Distribution Transformer
MDMS	Meter Data Management System
UCAIug	UCA International Users Group
SSOs	Standards-Setting Organizations
SOAP	Simple Object Access Protocol
WSDL	Web Services Description Language
EDL	Event Driven Language
EMS	Energy Management Systems
DMS	Distribution Management Systems
IEC	International Electrotechnical Commission
NIST	National Institute of Standards and Technology
SEP	Smart Energy Profile
OpenADE	Open Automated Data Exchange
CPI	Consumer/Prosumer Identity

Manuscript received October 18, 2012; revised March 15, 2013; accepted March 19, 2013.

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Digital Object Identifier 10.1109/JSYST.2013.2254980

II. Introduction

EMPOWERMENT of the end-consumers under the smart grid environment [1], [2] can be facilitated more effectively only when there is a standards development across the end-consumer-oriented services to promote the interoperability between the end-consumers, energy utility and the third party services. It opens up a lively smart grid paradigm which mutates the existing device-centric (Smart meters, sensors, homes, etc.) activities to the services-centric. The benefits are three fold: 1) efficient energy utility operations through reduction in procurement costs and better consumer engagement; 2) electricity bill savings and other incentives for the end-consumers; and 3) encouragement of more innovative end-consumer oriented third party services benefiting both end-consumers and utilities.

In an effort to develop interoperability standards at consumer levels, NIST and SGIP have coordinated with the NAESB to standardize the end-consumer energy usage data and interfaces for the third party access of smart meter-based information. This led to the development of the ESPI standard [3].

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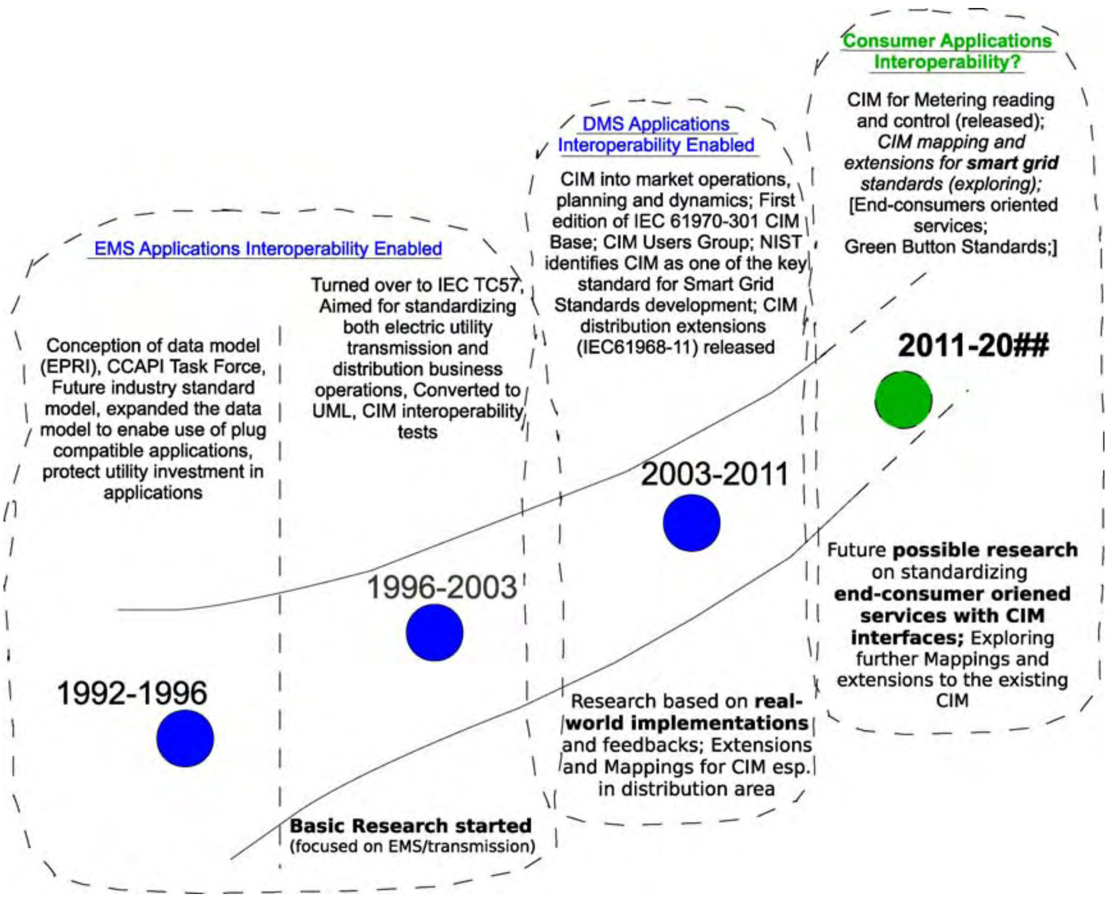

Fig. 1. Journey of power system common information models development

These efforts lead to the Green Button initiative [4], [5] that would help consumers to save energy and cut electricity bills by allowing them to track their own energy usage. This is the point of enablement of the operations of independent third party services for end-consumers[1] and the notion of green button standards (contributions made by the OpenADE, NAESB ESPI, and NIST SGIP-PAP 20, PAP10) has also started hereafter. The literature on the Green Button Standards is limited and information about the standards is mostly available through the parental websites [5]–[7]. We believe that this paper is the first of its kind focusing on the research made on green button standards. Typical green button files contain the details about the customer type, device, location, readings, interval data, summary information and power quality metrics. The initial green button preparation lacks in such considerations, as extended load records, prosumer activity records, representation of co-consumer transactions and frequency records. These extensions are presented in Section. V while discussion of the CIM extensions for integrating with the green button standards. Tools for the development of third party services around these emerging standards are also available [7], [8].

Most of the utilities' EMS/DMS systems are compliant to the CIM standard and use it as a *de facto* semantic reference [12]–[23], [27]–[37]. A chronological progress of CIM evolutions across various domains is shown in Fig. 1. PAP10 has made the energy usage information model consistent with the CIM [IEC 61968 Part 9] in few cases like defining "*Supplier Kind*," "*Reading Type*," "*Meter Reading*," "*Interval Block*," "*IntervalReading*" by using the names of classes, information elements and attribute in its latest release [10], [11]. This initial step is helpful in mapping the aforesaid standards, since the energy usage information model is the basic block in the Green button standards. In the present form, the Green Button standards are not mapped with the CIM for the enablement of utility side applications communications with the independent third party services built based on these emerging standards. To achieve this, it requires identifying the needs for communication between them. This paper identified the specific usecases which enable the integration of CIM & Green Button standards, and the possible scope for those applications' interoperability and further addresses the issues by laying down the framework for CIM and Green Button integration to enable the consumer oriented interoperable grid of future.

III. Drivers for CIM and Green Button Standards Integration

Authors expected that the future evolutions for the standards will be at the consumer-power retail peripheries and below

[1]The independent third party services referred in this paper are the ones which operate for the consumers by accessing their usage data from the utility portals, and intend to provide the feedback services at the discretion of the utility to the EMS/DMS

TABLE I
COMPARISON OF CIM AND GREEN BUTTON STANDARDS

Properties	**CIM**	**Green Button**
Year of formal inception	2001	2011
Data Preparation	Power network SACDA/ CIM oriented database	Smart meter (MDMS)/Energy utility
Data Exchange	Schema/ profiles	XML through ESPIs
Data/ Model Integration	with multiple applications at generation, transmission & distribution	with consumers and third-party services ***(back to EMS/DMS is proposed)***
Key Development Organizations	IEC TC 57 at present	OpenADE,NAESB ESPI, NIST SGIP-PAP 20, PAP10, EPRI
Timeliness	usually real-time	usually not real-time data, but few hours old data
Information access	CIM database at upstream level	MDMS and GB database (access through login) at downstream level

levels in which end-consumers will play an active role, where there is a high intensity of data and multiple number of independent third party applications. This is the motivation for the authors to explore the opportunities for integrating CIM and Green Button standards. Comparison of CIM and Green Button standards is shown in Table. I.

Although the applications at these levels are operating isolated with different objectives, there is a need for communication between them.

1) Growing innovative third party services operating on the consumer data (including BEMS) will be helpful for the utility in optimizing their operations and planning. Identifying the common required semantics at all levels and creating a separate profile for the third party access is necessary in this regard.
2) Future grid environment allows the visibility of the grid below the distribution transformers. The changing consumer (Industrial, Residential and Commercial) energy usage behaviors is significant and a continuous communicating mechanism with EMS/DMS is required for effective operations.
3) Latent demands created by the prosumer activities (including PHEV charging/discharging) affect the distribution grid operations. A standardized communication mechanism between the EMS/DMS and the third party services is essential.
4) Consumers supply migration in the future grid environment also to be dealt effectively as it should not create problems at the operations end.
5) Participation of consumers/prosumers in the open access transactions will also have significant impact on EMS/DMS and a standardized feedback system should be in place for effective operations & planning.

The gaps which are still persistent in enabling the end-to-end interoperability for smartgrids can be depicted from the Fig. 2. The crucial areas where there is immediate requirement for the formal integration of CIM and Green Button standards has been researched, and the findings are presented in this paper. While creating the interoperability framework at the downstream level, it should be ensured that it is consistent with the upstream existing standards as much as possible. This has not been considered at the time of green button preparation, as initially the energy usage information is isolated and a file transfer mode is only enabled [5]. Hence, the requirement for formal integration of upstream and downstream levels has arisen. More details about the integration of CIM and Green Button standards in the existing form is presented in the next section and further the proposed new classes are demonstrated with some application use cases in the Section. V. This paper focused only on the domain modeling integration of the CIM and Green Button standards while presenting the concepts.

IV. MODELING ISSUES AND TECHNIQUES FOR THE INTEGRATION OF CIM AND GREEN BUTTON STANDARDS

The question of integration of any two standards will arise only when there is a need for application communication between the actors who are conformed to those respective standards. Typically, the application communication can be achieved using enterprise integration techniques like service layers, EDM, etc. The term integration referred in this paper is at the abstract model, which is either through mappings or extensions, and thus it is independent of the protocol. On the basis of the needs as explained in the Section III, further in this section, the details about the identified modeling requirements for such kind of formal integration between CIM and Green Button standards is discussed. It is always recommended that the integration of the standards should be carried out by selecting one standard as a reference point and map the other one to that. Britton and Devo [30] have given some new directions for the CIM standards to change CIM from a direct role in standards interfaces to a design role. They have proposed the general requirements for CIM based interface standards, independent component interface standards methodology, and defined requirements for independent business process interface standards methodology.

In this paper, the necessity for integrating the CIM and Green Button standards is put forward while discussing the various important modeling issues for future requirements like hierarchical tagging of consumers, end-consumer migration, unique id of customers, electricity open access consumers, etc. Further, the work demonstrates the integration of the Green Button with CIM by taking CIM as the reference point due to its widespread industry usage.

Foreseen application interactions between CIM and Green Button standards are shown in the Fig. 3. The consumer oriented-services will communicate with the EMS/DMS applications on the requirement basis defined by the energy utilities, where the independent third party services will be useful for the both consumers and utilities. The different information exchanges identified are like SOAP, EPL through publish/subscribe basis, etc.

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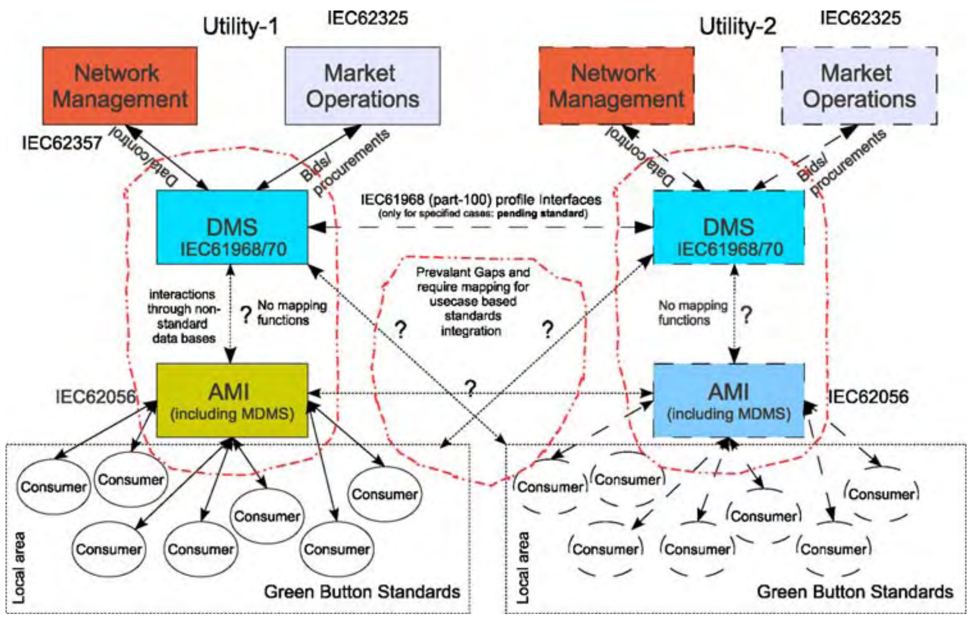

Fig. 2. Gaps to be filled by integrating the CIM and Green Button Standards

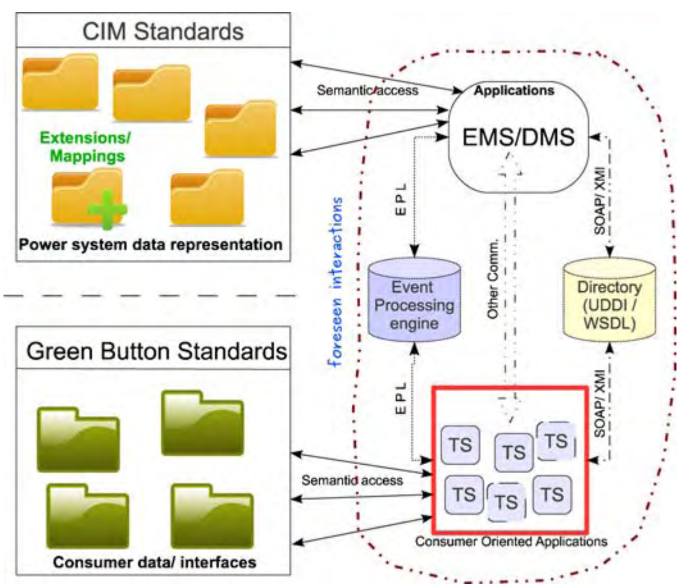

Fig. 3. Foreseen application interactions between CIM and Green Button standards

A. Hierarchical Tagging of Consumers

Smart grids empower consumers with the availability of the energy usage data, flexibility of renewable integration, and provides various pricing options from the utilities for encouraging active participation in the grid activities. As an effect of this environment, utilities are flooded with the high intensity of the consumer data. The classical consumer segmentation based on the connection types like industry, commercial, residential, agricultural, etc., cannot yield efficient insights about the consumers. Furthermore, consumers also provided with multiple options like supplier choice for the procurement of power. Utilities require various approaches to retain their consumers base to sustain in the competitive

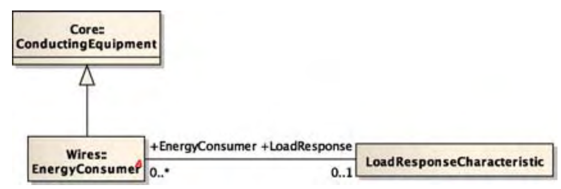

Fig. 4. Energy consumer model defined in the CIM [27]

environment. Some of the utilities are going for the profiling the consumers use of energy, and benchmarking that usage against similar consumers in the distribution grid. Utilities also require predictive analytics for analyzing consumers to offer good services. Third party applications are playing a crucial role in these exercises, not only for consumers but also for utilities. Energy consumer is inherited from the core package of the CIM. Fig. 4 illustrates the consumer model in the CIM.

To simplify these processes and for efficient high-level handling of the consumer data, this research proposes the *hierarchical tagging of the consumers*, where the consumer attributes will be defined according to their usage behavior at two levels in the distribution grid.

1) *Geographic Region:* It includes modeling of consumers as a separate extension class in the CIM with dynamic attributes such as skeptics, cost-conscious, eco-rationals, pro-actives, among others [24], across a geographic region. This class can have an association relationship with the existing energy consumer model and inherits from the CustomeKind.

2) *DT/HT Level:* Consumers hierarchically come under the distribution/high-tension transformers and are represented as a part of them. Hence, it includes the consumer segmentation and classification under the DT/HT levels and follows the same process as described in the geographic region.

Technique (1) is helpful for the third party services which pass generic messages to motivate the consumers based on predictive analytics for active participation in grid activities, and technique (2) is useful in network reliability based third party services using the customer data. At the same time, these attributes can also be defined in the Green Button EUI file of the consumer as an dynamic indicator.

```
============================================================
<title type="text">Dynamic Indicators of consumers</title>
 <content type="xml">
      <DynIndicators xmlns="http://iitb.ac.in/gbExt#">
        <ConsumerType>
          <GeographicIndicator>1</GeographicIndicator>
          <tfLevelIndicator>3</tfLevelIndicator>
        </ConsumerType>
============================================================
```

Proposed models based on these techniques are discussed in the next section.

B. Electricity Open Access Consumer/Prosumer Transactions

Electricity open access consumers (prosumers [25]) are special type of *consumers* who can buy/sell power across the system through different contracts without having any regional boundaries. With the flexibility given by the smart grid environment, authors envisage that the end-consumers can form coalitions to register as an open access transaction. The modeling and representation of these transactions in the Green Button formats have to be dealt in future. CIM has no specific model to represent such type of interactions except the communication as business as usual defined in the IEC62325, and hence it has to be incorporated in both of the standards to facilitate the integration. This can be made possible by defining an extension class to the CIM and also a mapping XML tag for accounting such transactions quantity in the Green Button files.

C. Consumers Unique Identification on Grid Basis

Visibility of the grid up to the granular layer will be the priority of the ISOs in the future. Many applications will run & configure on the basis of this data. For example, visualization of the entire grid as an integrated real-time visualizations including consumer contributions as ZoomIn/ZoomOut functions require the definition of the consumers in an unique form. In the CIM, the "*Location*," "*Service Location*," "*SDP Location*, "*Electronic Address*," "*Service Delivery Points*," and "*End Device Assets*" classes give the information about the customer location in the physical world. However, it requires the asset concatenated ID as shown in Fig. 5, which should be unique and representing any consumer who is residing anywhere in the grid. This is very much required to handle and streamline the high intensity consumer data, since it has an electric representation of the consumers. In order to standardize such modeling requirements, authors have proposed a new extension class which includes attributes as ISO, state, utility, transformer (DT/HT), consumer type, CPI (to differentiate consumer and prosumer activities), and a consumer number. This proposed new class has been inherited from the identified object. It is envisioned that the unique IDs enabled consumer analysis is computationally effective while using the CIM framework at enterprize level application integration, since there is no direct mechanism to address until now rather passing on through multiple core package classes in the existing CIM. The same tag can also embed into the green button format for consumer grid oriented identification. This has the potential to enable the subscription of EMS applications to the DMS during the grid monitoring.

ISO	State	Utility	Transformer	Cust.class	CPI	Customer no.
int	*int*	*int*	*string*	*int*	*string*	*string*

Fig. 5. Proposed Unique ID for Consumers

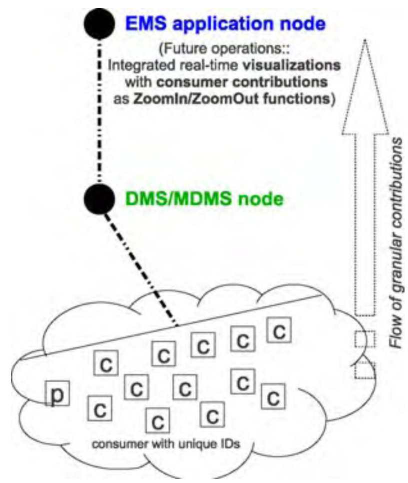

Fig. 6. Flow of granular information of consumers to applications been enabled by the Unique ID

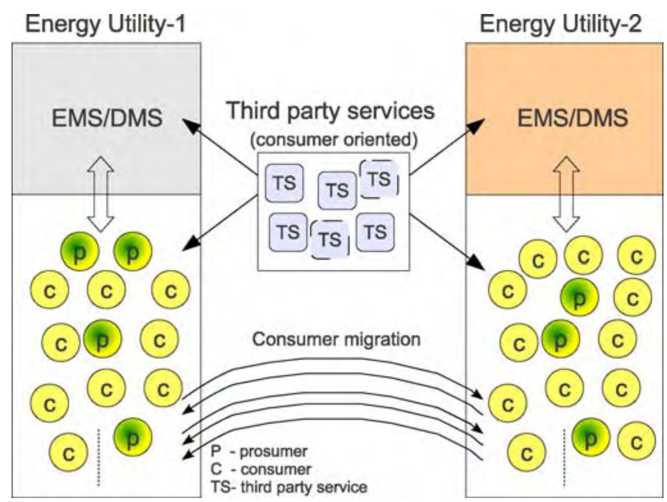

Fig. 7. Consumer/prosumer migration across utilities

The flow of granular information of consumers to applications enabled by the Unique ID at EMS/DMS levels are depicted in Fig. 6. The definition of the unique ID can also be extended below to the consumer point if more granularity is required. The privacy of the consumers can be safeguarded by encrypting the data, including the details of consumers to below the HT/DT levels. With this type of modeling there will be a flexibility to monitor only up to the HT/DT levels in the areas where strict privacy is desired. NIST guidelines on cyber-security [26] can be taken into consideration to address security and privacy issues while implementing in the real world.

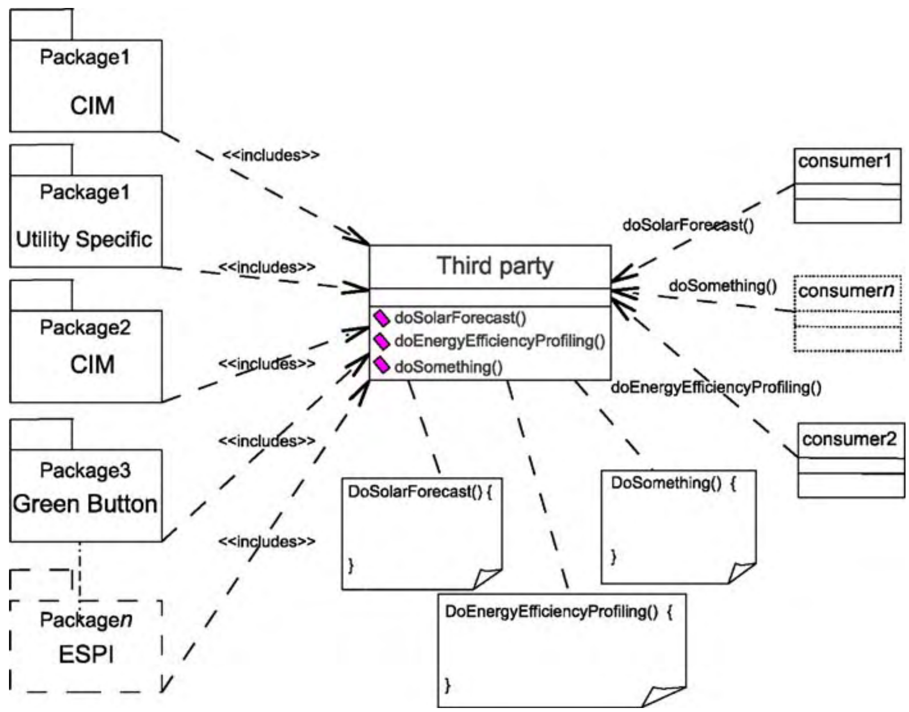

Fig. 8. Combined semantics for third part applications in Facade design

D. End-Consumer/Prosumer Migration

End-consumer/prosumer migration will become a common phenomenon in the smart grids for exploring the better services and pricing options. IEC62325-102 models the business processes in the competitive market environment. Identification of business process change of supplier is one of the case described in the standard from the metering provider interface as the reference [27]. However, the requirement during those cases is the transfer of the consumer historian from one utility to the other. This data will be useful for the other energy utility in services like load forecasting, benchmarking consumers, etc. Consumer/prosumer migration across the utilities is depicted in Fig. 7. This research has found that the semantic modeling to explicitly handle these cases is not available.

The energy consumer class in CIM is linked to the metering package through "*Energy Consumer–Service Delivery Point–Meter Reading–Meter Asset*." Here, it requires the new extension classes to capture the prosumer activities in CIM modeling and the corresponding transaction representation as an XML tag in the Green Button, by the virtue of which the consumers can avail their own complete data (consumer→prosumer). Further, it opens a platform where the consumer/prosumer while shifting the service can share their data through ESPI, and henceforth, the existing gaps in the CIM and MDMS profiling can also be addressed with the complete green button. More discussions on these models are presented in the next section.

E. Combined Semantics for Third Party Applications

Energy utilities' common vision is to build sustainable business practices to provide best services to the consumers. The priorities however vary from utility to utility. Realization of this would require the support of the innovative third party applications which operate on the consumer data. The output of these applications should be communicable with the EMS/DMS applications for enhancing the operations of the utilities. These third party services may be provided by some start-ups or well established companies. It is essential for the utilities to provide the selected semantics which enable the interoperability to spur inter-operable innovation. The common core semantics can be taken from the established international standards and the rest have to be defined by the utilities. In such a case the extensions are "*utility specific*" and the technique to model these efficiently where there are multiple third parties involved operating around the consumers is crucial. In order to facilitate this, a facade design based combined semantics accessible for the third party applications is proposed and the same is depicted in Fig. 8.

This kind of design provides the flexibility for the third party services to operate for the utilities which are following the CIM standard, and also for the consumers who have the Green Button files at the same time.

V. Proposed Models

The proposed semantic models for the CIM and corresponding XML tags in the Green Button standards are derived from the developed application usecases. The application usecases are built based on the identified requirements for future evolutions. Usecases are used at a higher level than within software engineering to present the big picture of the system interactions and focused on the functionality representation [9]. High level usecases diagram guided for integration of CIM and Green Button standards is presented in the Fig. 9.

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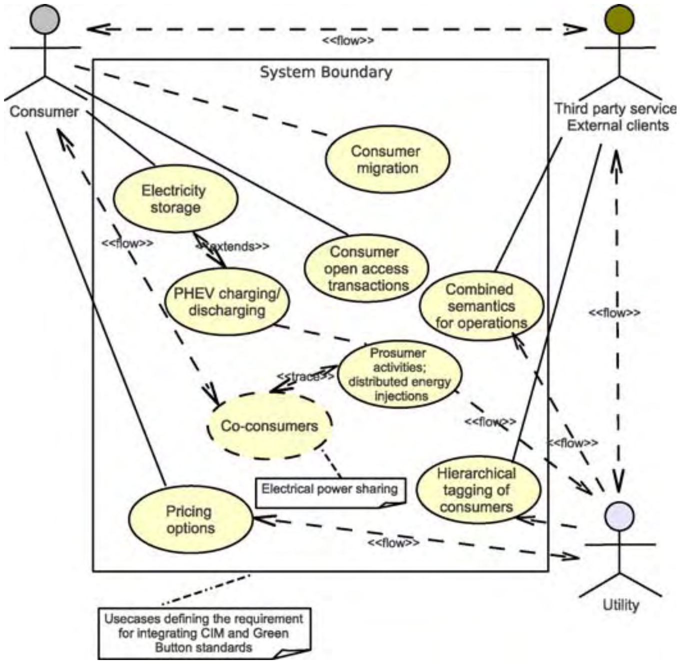

Fig. 9. High level usecases diagram guided for integration of CIM and Green Button standards

The high level usecases diagram presented here is structured and organized from the perspective of the consumers. It shows the information flow between the actors and the individual usecases like consumer migration, consumer open access transactions, prosumer activities, electricity storage under retail market operations, hierarchical tagging of consumers, etc. Each usecase prompts for semantic model extensions to the existing CIM and green button standards, which integrates the standards to enable the consumer oriented interoperability. The proposed models are incorporated in the existing CIM and green button standards without effecting the base packages and modeled as a dependency package. The combined packages including CIM and Green Button standards used in demonstrating the integration requirements are created in the enterprize architect version 8.0., and a screen-shot is shown in Fig. 10. The authors anticipate that the proposed CIM and extended Green Button domain models will provide an initial basis to encourage future efforts to integrate these standards with timely mappings and extensions.

A. Model for Prosumer Activity Records

Prosumers are the ones who both consume and produce the power [9]. They can be characterized as control over demand elasticity by virtue of their energy storage capabilities, and having the capacity to coalite with the other co-consumers to form consumer groups for power sharing, trading, etc. Accommodating such a phenomenon in the existing standards is necessary for encouraging the end-consumer oriented third party services. In this paper, the authors have proposed the prosumer activity records for the green button standards and the corresponding extension classes to the existing CIM. The extensions for incorporating the prosumer activities are shown in Fig. 11.

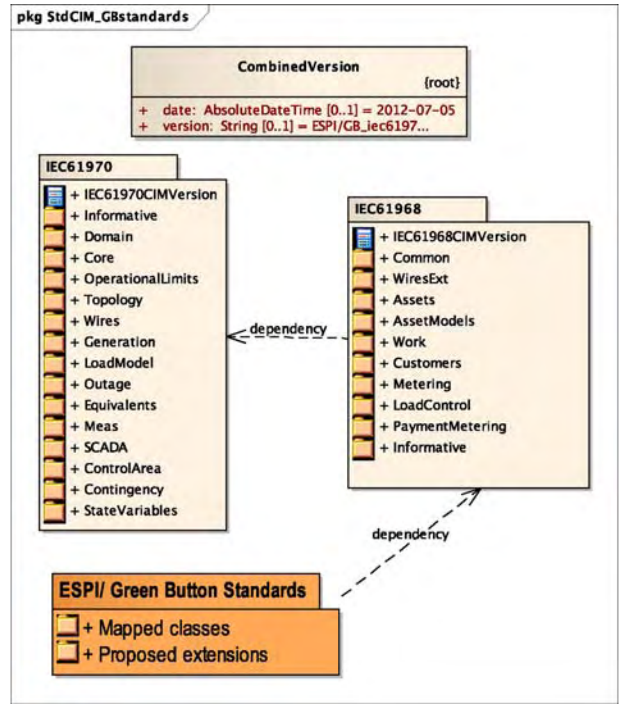

Fig. 10. Combined package model of CIM and Green Button

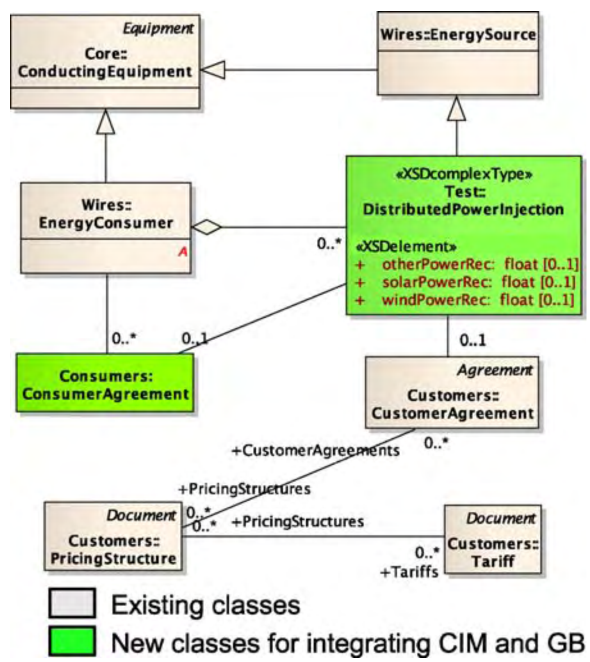

Fig. 11. Extensions for incorporating the prosumer activities

The proposed CIM classes are "*Distributed Power Injection*" and "*Consumer Agreement*," where the class "*Distributed Power Injection*" records the measurement of the consumer owned distributed power injected into the grid, and "*Consumer Agreement*" is to define the agreements between the prosumer/consumers for power sharing. The envisioned concept of consumer/prosumer power sharing is like during the vacations or in off-grid mode or in high price hours the prosumers can share their generated power with the co-consumer

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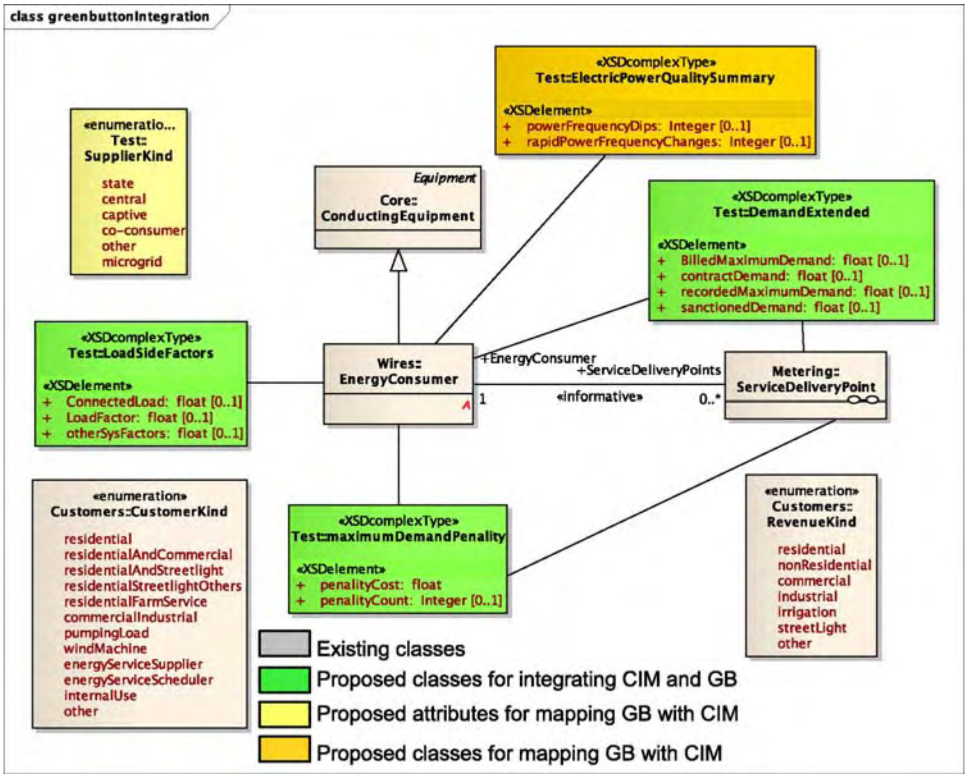

Fig. 12. Proposed extensions for complete demand management

on the basis of a predefined agreement. The "*Distributed Power Injection*" class has the attributes of solarPowerRec, windPowerRec and otherPowerRec, with the relationships of aggregation to "*Energy Consumer*," association with "*Consumer Agreement*" and inheritance from "*Energy Source*." The combined classes "*Distributed Power Injection*," "*Energy Consumer*," and "*Consumer Agreement*" represent the prosumer activities. The corresponding proposed green button XML tags are solarPowerRec, windPowerRec, and otherPowerRec along with the related cost tags. The existing "*cost*" tag defined in the green button can be used as it is for defining the purchase/selling cost during any interval block.

B. Models for Extended Records

The initial version of the Green Button focused on defining the basic energy usage information. Most of the demand and load records important for the advanced analysis about the energy usage are not taken into account. For example, "*connected load*" at the consumer premises important for consumer benchmarking is not defined. However, a provision has been given to define the extensions for the utilities. In this paper, authors have identified the necessary extended demand and load records which aids for the better operation of the consumer oriented third party services. The identified tags are as follows: ConnectedLoad, LoadFactor, otherSysFactors, BilledMaximumDemand, contractDemand, recordedMaximumDemand, sanctionedDemand, maximumDemandPenality::penalityCost, and maximumDemandPenality::penalityCount. These green button tags are integrated into the CIM using three extension classes namely, DemandExtended, LoadSideFactors, and maximumDemandPenalty. The CIM extensions which enable the complete demand management along with their relationships with the existing classes are shown in Fig. 12.

The identified mapping classing for integrating the CIM and Green Button standards for the existing versions are "*Supplier Kind*" and "*Electric Power Quality Summary*." The mapping has been done by adding green button XML tags along with the new ones as the additional attributes in the existing CIM "*Supplier Kind*" class, and creating a new class "*Electric Power Quality Summary*" in the CIM.

C. Consumer Unique Identification Model

To satisfy the consumer modeling requirements as explained in the Section. IV-C, a separate extension class representing the consumer grid identity is proposed here. The extension class is shown in Fig. 13.

The proposed class "*consumer Unique ID*" exhibits an inheritance relationship with Core::IdentifiedObject and an association with EnergyConsumer. It had the attributes of isoIdentity, stateIdentity, utilityIdentity, transformerIdentity, customerClass, CPI, and consumerNumber.

D. Consumer Hierarchical Tagging Model

In order to meet the consumer tagging requirements based on segmentation, benchmarking or ranking consumers for identifying potential saving DTs, as discussed in Section. IV-A, the authors have proposed the new class namely, "*Consumer Tags*," which has the attributes of skeptics, costConscious, ecoRationals, proActives, and others.

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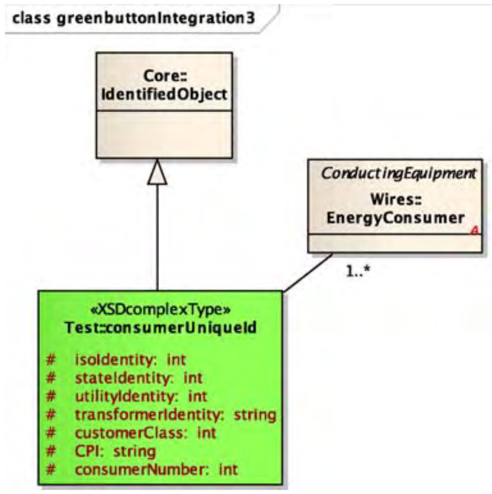

Fig. 13. Extension class to CIM for representing the consumer unique ID

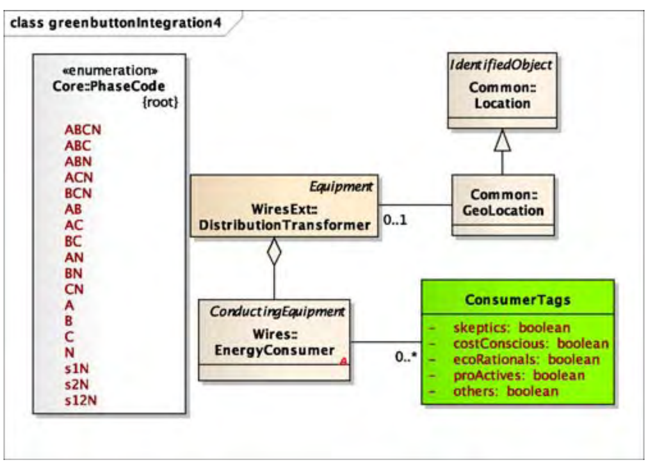

Fig. 14. Consumer hierarchical tagging model

The proposed extension class with the relationships to the existing CIM as shown in Fig. 14. Similarly, the consumer tags can also be defined in the green button files. This gives a good clue about the utility-side benchmarking criteria to the consumer used third party services for suggesting any specific recommendations to cater for the own needs.

```
============================================================
 <content type="xml">
      <consumerTags xmlns="http://iitb.ac.in/gbExt#">
        <ConsumerType>
          <GeographicIndicator>1</GeographicIndicator>
          <tfLevelIndicator>3</tfLevelIndicator>
        </ConsumerType>
============================================================
```

E. Electricity Open Access Consumer/Prosumer Transaction Records Model

The provision for explicit representation of electricity open access consumer/prosumer transaction records is not available in the CIM (even in the market part- IEC62325) and Green Button standards. However, emerging retail markets and wholesale market player interactions require such provisions to measure the openness of the consumers in market participation. The proposed class with the relationships to the existing CIM as shown in Fig. 15.

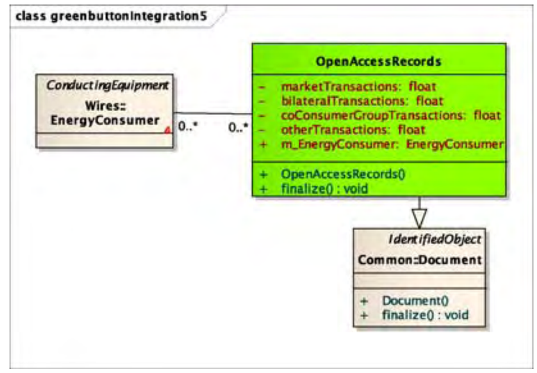

Fig. 15. Electricity open access consumer/prosumer transaction records model

TABLE II
SIMULATION RESULTS OF THE PROPOSED MODELS

	CIM	Green Button
Prosumer activity model	✔	✔
Extended demand model	✔	✔
Consumer unique identification model	✔	N/A
Consumer hierarchical tagging model	✔	✔
Electricity open access consumer/prosumer transaction records model	✔	✔

The proposed class "*open Access Records*" has the attributes of marketTransactions, bilateralTransactions, coConsumerTransactions, and otherTransactions. The generalization relationship has been made intentionally with the "*Document*" (EnergyConsumer → ServiceDeliveryPoint → CustomerAgreement → Agreement → Document), which is helpful in optimizing the implementation process.

```
============================================================
 <content type="xml">
      <openAccessRecords xmlns="http://iitb.ac.in/gbExt#">
          <marketTransactions>10</marketTransactions>
          <bilateralTransactions>254</bilateralTransactions>
          <coConsumerTransactions>2</coConsumerTransactions>
          <otherTransactions>0</otherTransactions>
        </ConsumerType>
      </openAccessRecords>
============================================================
```

VI. TEST RESULTS

CIM/XML and green button files for the proposed models are created using the publicly available sample data of PG&E [38] for the simulation purposes. Simulation results of the proposed models which have been successfully achieved are shown in Table. II. Furthermore, some of the proposed extension classes and the corresponding green button XML tags are tested by creating different practical scenarios. For example, a case of using consumer unique ID for representing the open access transaction is simulated and observed that the *consumerUniqueID* can enable the usage of *OpenAccessRecords* class effectively.

A Python Script output during the simulation of a open access transaction with and without consumerUniqueID is

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

Fig. 16. Sample Python script output during the simulation of an open access transaction with and without consumerUniqueID

shown in Fig. 16. Energy usage information XML files contains the customer energy usage data and their references to the XSD and XSLT. XSD is the XML schema which describes the definitions of the XML tags defined in the energy usage information. The possible extensions to the existing green button standards are represented in the form of XML tags and the corresponding sample XML schema used in the applications is shown in the Appendix.

VII. Conclusion

This paper stressed the necessity for integrating CIM and Green Button Standards to enable the consumer oriented interoperability with other power system levels. The research work presented brought to the fore the capabilities of consumer oriented interoperable systems in future. A review of the work carried out by the various standardization bodies in these areas was presented. Among all the green button standards, "*Green Button*" in specific, is already adopted by most of the utilities and in parallel, independent third party service providers have also started deploying applications to help the end-consumers. The new grid environment, which, envisages active end consumer oriented services, will require communication between all the levels of the system. Hence, a vision for the utilities to streamline these independent third party services to get benefited is essential. This paper identified some of the ways to achieve the same. A conceptual background was built to identify the necessity, as well as to substantiate the domain model integration of CIM and Green Button standards with mappings and extensions. In this process, several use-cases like hierarchical tagging of consumers, End-Consumer Migration, Unique ID of Customer, Electricity Open Access Consumers, and combined semantics for third party services were presented. The mappings and extensions in both the standards were evolved, based on the existing utility practices and foreseen future evolutions of the grid. The proposed domain models were also tested on the practical data of PG&E, and IEEE test systems for verification. It involved the generation of the CIM XML and Green Button files for the proposed models. Furthermore, this research *per se* can be a useful input to the SSOs and technical committees and a potential point of departure for future investigations.

Appendix

Sample XML Schema Description of the Proposed Extensions Based on Green Button Standards

```
<?xml version="1.0"?>
<xs:schema targetNamespace= "http://www.iitb.ac.in/gb_espi/1"
 xmlns="http://www.iitb.ac.in/gb_espi"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" version="1.0">
      <xs:annotation>
            <xs:documentation>Proposed extensions to ESPI/
Green Button standards</xs:documentation>
      </xs:annotation>
      <xs:element name="consumerUniqueId"
type="consumerUniqueId"/>
      <xs:complexType name="consumerUniqueId">
            <xs:annotation>
                  <xs:documentation>An encrypted unique
identification marking given to each consumer for identifying
their state, utility and usage point
                  </xs:documentation>
            </xs:annotation>
            <xs:simpleContent>
                  <xs:extension base="xs:string"/>
            </xs:simpleContent>
      </xs:complexType>
      <xs:element name="RenewablePowerInjection"
type="RenewablePowerInjection"/>
      <xs:complexType name="RenewablePowerInjection">
            <xs:sequence>
                  <xs:element name="solarPower" type="float"
 minOccurs="0" maxOccurs="1">
                        <xs:annotation>
                              <xs:documentation>A
measurement of the customer owned solar power injected
into the grid    </xs:documentation>
                        </xs:annotation>
                  </xs:element>
      </xs:complexType>
      .
      .
      .
</xs:schema>
```

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