Smart Grid Standards Conformed Cloud BasedDemand Side Management Tools

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Abstract

Green button data format is the upcoming smart grid standard for promoting the interoperability between the smart meters. This gives the flexibility for the consumers to download their respective usage data in a common format, where it can be used for analysing on any third party services. In this paper, a cloud based service for demand-side management conforming to the green button standard has been reported. Using this service, the users can upload their multiple green button energy usage data files for managing their demand in real-time and understanding their energy usage patterns for potential savings on energy costs. The service has the functionalities of analysing energy usage, managing peak usage, future load projections, renewable switching suggestions, and capability to analyse the external data like weather parameters for assisting in taking wise decisions.

I. Introduction

Smart grid is going to revolutionize the way how end-consumers are consuming the electricity. End-consumer oriented services are the key for an effective smart grid implementation. In this direction, a new smart grid standard termed as "Green Button" has been introduced in year 2011 to facilitate the availability of the end-consumers energy usage data in a common format. It provides freedom to the end-consumers to study their power consumption patterns in any third party services. An opportunity to save money on electricity bills is the outcome of using these services.

With reference to the upcoming smart grid standards, we built smart grid standard compliant cloud based demand-side management tools for the end-consumers and made it available for 27 million end-consumers for free usage. This platform provides various tools which not only suggest the saving measures, but also projects the future consumption and recommends the renewable integration/ deploying suggestions based on their energy usage for the available local tariffs. Cloud computing provides a whole new deployment model for enterprise web-applications. It emerged from several computing techniques like grid computing, cluster computing, software-as-a-service, utility computing, and autonomic computing.

Reference [3], gives an introduction to the cloud services and smart power grids. It explains various concepts of integrating power system applications on cloud. A model for smart grid data management based on specific characteristics of cloud computing, such as distributed data management for real-time data gathering, parallel processing for real-time information retrieval, and ubiquitous access is presented in reference [4]. Reference [1] proposed a energy information systems, which manage energy consumptions over internet. The authors presented an innovative decision-support system and cloud computing software methodology that brings together energy consultants, consumers, energy services procedures and modern web interoperable technologies. Authors also tried to integrate the smart meters on the cloud. In reference [2], authors proposed concept of cloud provider and some real-time demand response services which operates on cloud. In this paper, the implementation of the cloud based smart grid standards compliant demand-side management applications is presented. So far, such kind of work has not been reported in the literature. The demand-side management applications have the capability to analyse consumer energy usage, manage peak usage, future load projection, suggesting renewable energy switching/ deployment, and to analyse the external data like temperature, and humidity. The outcome of using these applications by any end-consumer can be accounted in saving the money and environment.

The rest of the paper is organized as follows: An introduction to the smart grid green button standard is presented in the Section II. Section III introduces the key concepts of cloud computing. The conceptual architecture of cloud based demand-side management tools is presented in Section IV. Design of Demand side management tools is presented in the Section V. Conclusions and future work are discussed in Section VI.

II. Green Button Standard

National Institute of Standards and Technology (NIST) and its contractor Electric Power Research Institute (EPRI) led a series of workshops to identify key standards of the Smart Grid, and importantly, to identify critical gaps in the coverage of standards. Among the most prominent, one such gap identified the need for standardized energy usage information to inform the consumer [5].

Green Button is the standard which facilitates electricity customers to securely download their own easy-to-understand energy usage information from their electricity supplier. Equipped with this information, consumers can use a growing array of new web and smart-phone tools to make more informed energy decisions, optimize the size and cost-effectiveness of solar panels for their home, or verify that energy-efficiency retrofit investments are performing as promised. Adoption of this standard by energy utilities allows software developers and other entrepreneurs to leverage a sufficiently large market to support the creation of innovative applications that can help consumers make the most of their energy usage information [6]. Adoption of demand-side management schemes require customer feedback and engagement to enable them to benefit. Many electricity regulators are interested in ubiquitous low cost green button capabilities to enable consumer engagement and support return on investments. An ecosystem of goods and services can be built around the green button standard, where the web applications, desktop applications and applications within the home can seamlessly integrate. The sequence diagram of the energy information defined in the green button standard is shown in Fig. 1.

III. Cloud Computing

Cloud computing is the delivery of computing and storage capacity as a service to a community of end-recipients. The name comes from the use of a cloud-shaped symbol as an abstraction for the complex infrastructure it contains in system diagrams. Cloud computing entrusts services with a user's data, software and computation over a network [9]. Cloud computing relies on sharing of resources to achieve coherence and economies of scale similar to a utility (like the electricity grid) over a network (typically the Internet) [10]. It is the broader concept of converged infrastructure and shared services. There are three types of cloud computing: [8]

1) Infrastructure as a Service (IaaS)
2) Platform as a Service (PaaS) and
3) Software as a Service (SaaS)

Cloud providers built data-centers by deploying hardware, networking, storage, distributed systems, etc. and provide the same as a service. Cloud users rent storage, and computation from them and this whole setup is termed as Iaas. PaaS is helpful for the developers in creating the services, who do not want to build their own cloud. The platform for these developers is made available through the cloud providers. SaaS provides flexibility to the users to rent application software and databases. Demand side management tools reported in this paper are using the public cloud where a model of IaaS, PaaS, ans SaaS has been adopted. In our work, end users access cloud-based applications through a web browser or mobile app while the development software and user's data are stored on cloud servers. The use of cloud computing allows applications to run faster with improved manageability and less maintenance, and enables IT to more rapidly adjust resources to meet fluctuating and unpredictable users demand.

IV. Conceptual architecture for deployment of cloud based demand-side management tools

A conceptual architecture for deployment of cloud based demand-side management tools is shown in Fig. 2. The main components in the architecture are the public cloud management, cloud interface layer, and user communication interface layer. The public cloud management consists of the infrastructure maintained by the cloud provider, and a software deployment interface for the developer. The demand-side management tools reside in the developer software deployment arena and interfaced to the cloud interface layer. This interface opens its connections with the world wide web (Internet) and any user who want to access the demand-side management services can connect through the user communication interface layer. A firewall for the purposes of cyber-security is maintained at both the cloud interface, and user communication interface layers.

V. Demand Side Management Tools

Demand-side management at the end-consumer premise is essential to save the energy costs both for the

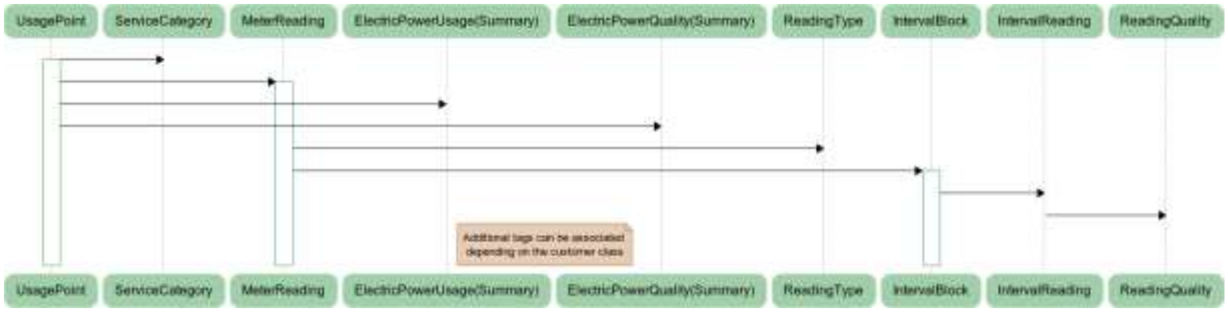

Fig. 1. Sequence diagram of energy usage information (XML) represented through green button standard

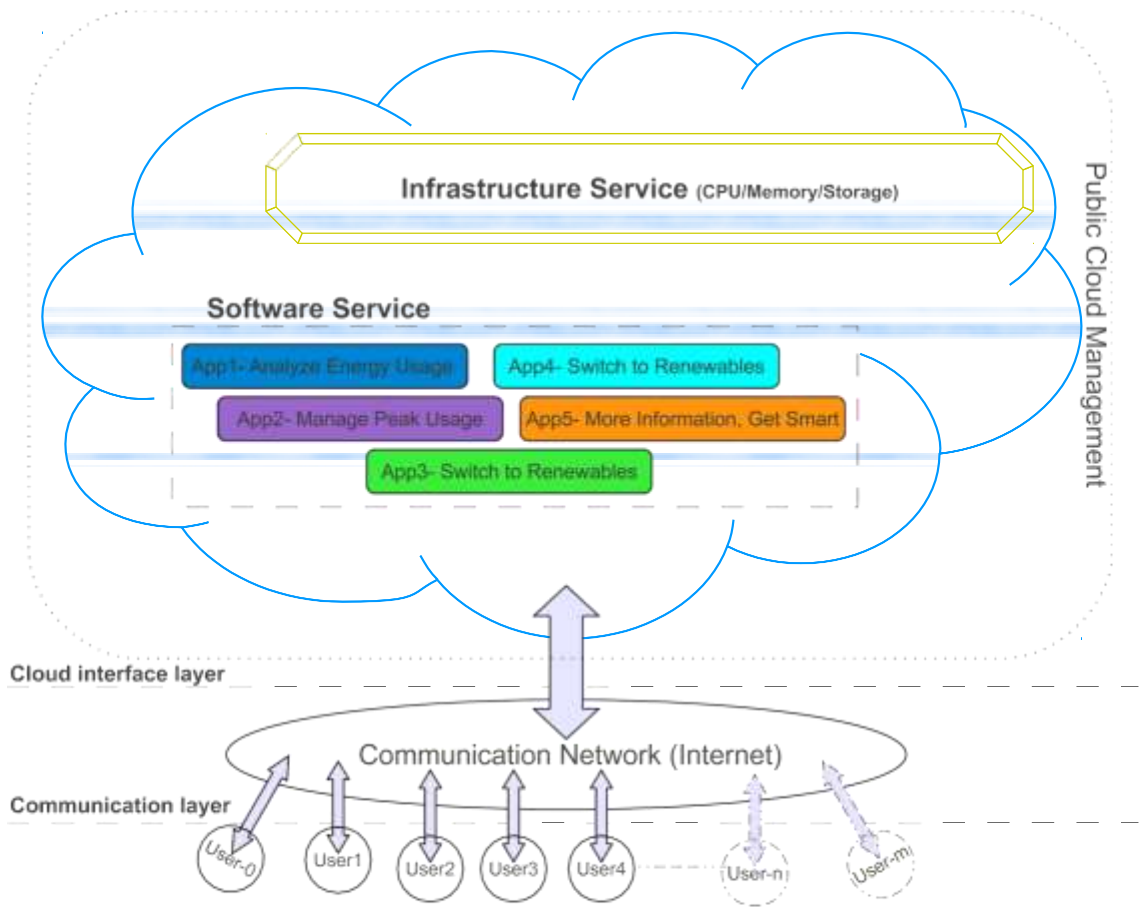

Fig. 2. Conceptual Architecture of Cloud based Demand Side Management Tools

electricity supplier and themselves. In this process, the end-consumer has to respond to the high cost periods by altering the regular demand. This requires some handful tools for taking right decisions, which reflect the savings in both short-term and long-term. The demand-side management tools introduced in this paper have the same features, and also conforming to the smart grid standards in promoting the interoperability at the end-consumer level.

Energy usage data of the end-consumer is available in green button XML format. This requires a software adapter to convert the files into some useful information. The XML schema prepared for the energy usage data in green button standard is shown in the Fig. 3. Using the green button standard definitions, a separate parser-cum-adapter is written and made available on the software interface of the cloud. The applications running using this information are as follows:

```
<xs:complexType name="IntervalBlock">
  <xs:annotation>
    <xs:documentation>Time sequence of Readings of the same ReadingType.</xs:documentation>
  </xs:annotation>
  <xs:complexContent>
    <xs:extension base="IdentifiedObject">
      <xs:sequence>
        <xs:element name="interval" type="DateTimeInterval" minOccurs="0">
          <xs:annotation>
            <xs:documentation>Specifies the time
            period during which the contained readings were taken.</xs:documentation>
          </xs:annotation>
        </xs:element>
        <xs:element name="IntervalReading" type="IntervalReading" minOccurs="0" maxOccurs="unbound
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Fig. 3. XML schema in compliance with green button standard

1) Analyze Energy Usage
2) Manage Peak Usage
3) Look into the Future
4) Switch to Renewable
5) More Information, Get Smart

These applications are free to use and available at http://www.gridfortunecom/app. The only requirement for using these applications is to have a valid green button energy usage file, which can be downloaded from the energy supplier portal. The analysis and results discussed in the preceding sub-sections are carried out on the PG&E users green button files available at [7].

A. Application-1: Analyze Energy Usage

"Analyze Energy Usage" can help user to analyze their energy usage and recommends how they can save money on that usage. The features of this application includes a preliminary overview on the usage patterns, while identifying any unusually high periods. With that information, it also recommends ways in which user can save more money on their electricity bill. After running this application on the cloud, it gives various insights into the user energy usage. Fig. 4 shows the distribution of average cost paid to the electricity supplier across the hourly time intervals. Expected cost range, and consumption between minimum & maximum range is available in the Fig. 5. This indicates the user relative consumption w.r.t the cost of electricity.

The usage of the electricity is classified under five categories, namely, early morning (00:00 am - 6:00 am), morning (6:00 am 12:00 am), afternoon (12:00 pm - 18:00 pm) , evening (18:00 pm - 20:00 pm), and night (20:00 pm - 00:00 pm). The consumer electricity consumption is captured through the mean-variance metric, and the instance where the user has crossed the baseline is treated as the unexpected usage. The unexpected electricity high use distribution is shown in the Fig. 6.

Fig. 4. Distribution of average cost paid to the electricity supplier

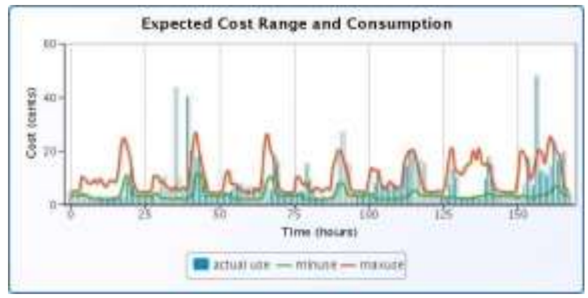

Fig. 5. Expected cost range and consumption

The base cost paid to the utility or electricity supplier is shown in the Fig. 7. The base electricity usage of the user is shown in the Fig. 8. Using the unexpected usage data, the possible savings are calculated and shown in the Fig. 9.

B. Application-2: Manage Peak Usage

"Manage Peak Usage" is specialized to help user to manage their power usage at the peak (high cost) usage periods. Using a robust optimization technique, the feature takes into consideration the consumer preferences,

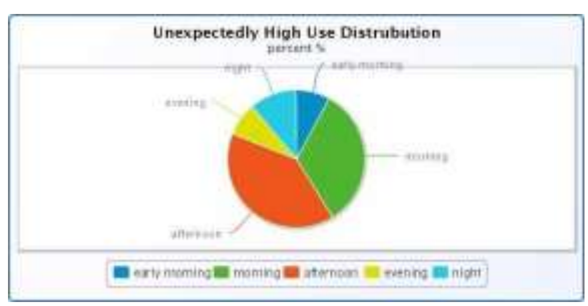

Fig. 6. Unexpected electricity high use distribution

Fig. 7. Base cost paid to the utility or electricity supplier

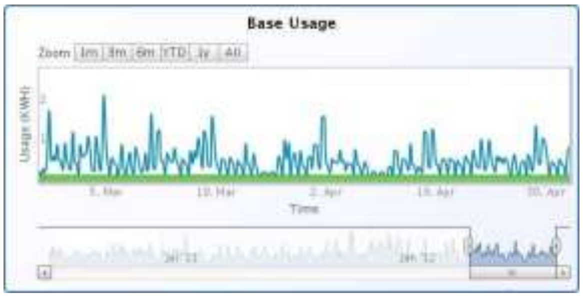

Fig. 8. Base usage (24x7)

such as day of the week and preferred level of consumption, to help them optimize how they use the electricity and how they want to decrease the consumption levels.

The application interface is shown in the Fig. 10. It provides three options for the user to pick, i.e, strict savings, moderate savings/comforts, or strict comforts, and accordingly, optimization will be run for suggesting the typical load scheduling patterns.

C. Application-3: Look into the Future

"Look into the future" projects the future power usage patterns. This feature is based on consumer input and customized calculations to change ones energy usage over a desired period of time and thus to save money.

Fig. 9. Possible savings drawn based on the regular consumption patterns

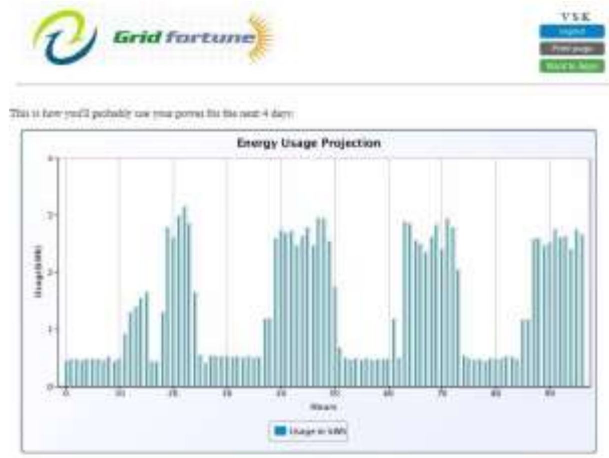

Fig. 11. Future energy consumption projections

The future projections are drawn using the regression techniques and a sample running interface is shown in the Fig. 11.

D. Application-4: Switch to Renewable

"Switch to Renewables" recommends when it is most profitable to connect user renewable energy sources, such as solar, fuel cell, and wind, to the grid and for personal use. It takes into account consumption levels and the cost they are currently paying on electricity. This feature, with consumer inputs about desired investment levels and location, provides optimal recommendations on renewable energy usage to save and earn money. The application interface is shown in the Fig. 12.

E. Application-5: More Information, Get Smart

"More Information, Get Smart" can provide more money saving methods by taking into consideration temperature, humidity and wind speed. The user must upload a file with additional information, through which the feature will recommend the best way to reduce energy usage and save money.

Using this application, the user can also download the green button standard data as an excel file. The application interface is shown in the Fig. 13.

VI. Conclusions

This paper has introduced the free cloud based demand-side management tools conformed to the smart grid standard called green button to the electricity end-consumer community. These tools are helpful for the consumers to manage their demand to reduce the energy costs. Furthermore, the effective usage of these tools by the end-consumers will also drastically impact on the

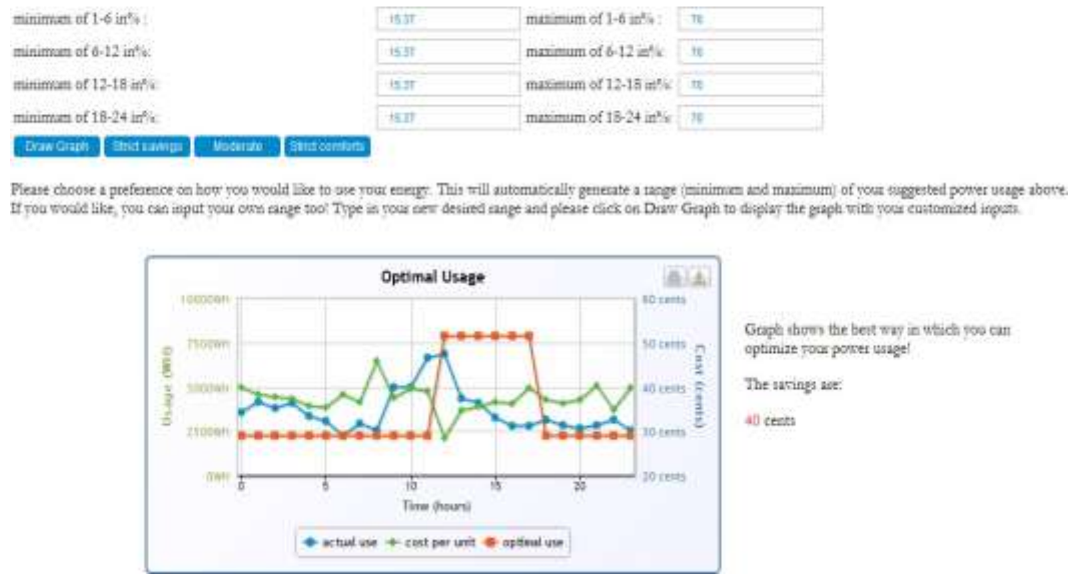

Fig. 10. Interface of manage peak usage

Fig. 12. Application interface of “switch to renewables“

costs of power procurement of the energy utility. Green button standard is currently in practice only in the US and European nations. Rest of the nations should also localize the standard as per their local requirements due to its prime importance in encouraging the demand-side management.

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