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# Energy Visualization for Smart Home

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**Abstract**

Smart home energy system visualization has an important development in the field of smart home. How to allow users using internet or hand phone application (APP) to know the household electricity consumption in real time has an important impact on improving the household electricity efficiency and changing users' habits of using electricity. In this paper, it firstly summarizes the state-of-the-art research of home energy system visualization techniques and analyzes their values and lacks. Secondly it proposes a visualization program of smart home energy based on the smart phone APP. The program not only allows users to intuitively understand the household electricity consumption, but also gives users the ability to optimize home energy efficiency following their habits of using electricity, in order to achieve home energy saving, efficiency and convenience.

*Keywords*: Energy Visualization; Smart Home System; Household Electricity; Smart Phone APP

## 1. Introduction

In last couple of years, energy efficiency and saving has become a key problem due to the increase of energy consumption, energy prices, and concerns about the environmental changes. The research on household electricity is an important topic in the field of energy consumption research [1]. Smart home system makes the management of household electrical appliances more systematic, and makes home energy management more easily. Many countries have done a lot of research on the visualization of household energy management, including Google and IBM, etc. For users, comprehensive and real-time visualization of electricity is very important, which allows users to timely know whether there is a waste in energy consumption [2]. The research in this field is more significant from the viewpoint of long-term statistics which affects users' behavior of electricity consumption, so as to achieve a smart use of electricity. And visualization of such systems will help interactively improve users' behaviors.

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## 2. Related work

Following a greater interest in energy efficiency, as well as visualization, several pilot projects were rolled out across the U.S.A., including one by CenterPoint Energy and the U.S. Dept. of Energy [3], and another one by Alliant Energy and IBM [4]. One of the objectives of these projects is to analyze the current consumption behavior of users, and investigate what role they can/want to play in reducing electricity consumption and thus increase energy efficiency.

Initial results seem to suggest that pervasive technologies can help raise awareness of electricity consumption among users. For instance, 83% of participants reported their consumption behavior's changing once consumption data were made available to them via in-home displays (IHDs) [3].

In recent works, a public-private partnership supported by the National Institute for Standards and Technology has developed Green Button Data, a standard for the distribution of electricity usage data [5]. A customer can visit their utility web portal, login and download his own power consumption details by using this Green Button. It is now a standard for the dissemination of electricity consumed data. This Green Button standard will further simplify the development of applications to get together electricity consumption data with any other third party data streams to offer an insightful view into consumers' energy consumption [6].

Major corporations such as Google and Microsoft, as well as several transmission and distribution providers via their coalition in Smart Meter Texas, are also active in this field. Google and Microsoft released PowerMeter [7] and Hohm, respectively. These are Web-based applications that let users access their electricity consumption data and visualize them on interactive charts. Notwithstanding the support from Google and Microsoft, both projects are being discontinued due to interest below expectations.

We argue that the limited utility in reducing the energy consumption is one of the reasons why these applications have not attracted more users. Neither Google PowerMeter, nor Microsoft Hohm, nor Smart Meter Texas offer a way to answer questions such as:

- The visual data is simple so as to make it difficult to personalize the applications.
- The lack of intelligent data analysis and recommendations results in the poor user experience.
- The data did not get the feedback of the use that whether it can be combined with the third party system to form an intelligent energy network or not?

In this paper, it proposes a smart home energy visualization program based on smart hand phone APP. By using this APP which prevents the deficiencies reported in above research works, the user can have more intelligent and personalized experiences in energy visualization management.

## 3. Proposed visualization program for smart home energy consumption

Although the smart home system has been developed for some years, there are still many deficiencies in its energy management part according to some latest research reports. In this paper, a smart home energy visualization program based on smart phone APP is proposed. It can not only let users see the household electricity consumption more intuitively, but also analyze and process the relative data more intelligently [8]. The program can help users find their bad habits and give them the optimized results as good habits for reference.

There are mainly 3 parts in the program: initial electric data acquisition and preprocessing, key power figure statistics and user behavior analysis, optimization plan and intelligent feedback.

### *3.1. Initial electric data acquisition and preprocessing*

In this program, the traditional smart home system as mentioned in others' work is only used as the core part of data acquisition. The initial electric data like working power, current, voltage, etc., are all needed and acquired from all kinds of home appliances through traditional smart home systems.

Then all the data are recorded in a standard database and then preprocessed with uniformed formats. The collection of these data is used to make electricity consumption statistics per day from the smallest unit to the whole power system in the home.

### *3.2. Key power figure statistics and user behavior analysis*

With the work of data acquisition and preprocessing, it is in fact very hard for common users to really understand so many initial data. How to help users intuitively understand them is the main target of the program. To realize this, the key power figure statistics are needed to be done and the relative user behavior analysis are also needed.

The design is based on a smart hand phone APP. The APP is used to convey the intuitive energy system information to users and provide users some intelligent suggestions. At the same time, users can use the APP directly to control the relative appliances via the smart home energy system. The App will receive real-time data from the smart home energy system and then record and analyze the data further [9].

And the APP will be widely adapt to different users. So taking into account the amount of users and individual differences, the APP will provide users with the choices of three modes of work: universal mode, personalized mode and energy saving mode.

Universal mode is a behavior marked as a good use of electricity. The APP will compare and assess the excellent behavior from users' behavior habits via network aggregation [10]. The public can vote to elect an accepted good behavior of electricity use as a universal mode. Personalized mode refers to the user's special activities which may use electricity in special periods. Users can choose personalized mode which will not refer to the public selection. Energy saving mode is defined with the standard work hours provided with the upper limit of electricity from the user to control the electricity consumption automatically [11]. All modes will be updated according to the constant update from the network. By selecting the mode of operation, a user can also contribute to the intelligent network by uploading his own statistical power data via his APP. This is also a kind of big data collection which will help for further research and applications.

At real working status, the smart home energy system communicates with the users' APP in real-time, so that the APP can receive electricity data at a setup rate. After this, the software draws real-time electricity curve of household electricity and ranks the household electrical appliances by electrical power consumption. Through the key power figures and their consumption rankings, the user can understand the electricity situation more intuitively [12].

Visualization by key power figures is just a part of the APP. In our program, another important part is to do users behavior analysis based on the figures and data. It can analyze users' electricity using habits based on electricity data over a period of time. Then it can give an automatic ranking for users' habits based on the rules extracted from the internet or defined by experts. The basis of this ranking is on the statistics of the time interval, duration and usage frequency of household appliances. The APP will automatically discard the bad data like high or low voltage caused for instance by a sudden power break for the consideration of robustness. And besides of good or bad user behaviors judged from these rankings, it is also possible to find some abnormal status of the appliances including that they may be too old to be fixed or there may be somewhere power leaking.

### *3.3. Intelligent feedback and optimization plan*

After the judgement of the users' electricity using habits, the APP will give users some intelligent feedback with an optimal electricity using improvement program. The form of the improved plan is to suggest users how to use each appliance more suitably, even smartly, like shutting down air conditioner when there is no person in the room, tuning a lower cooking temperature when little water left in the pot, etc. The initial data collected by the APP will be uploaded to the internet database anonymously [13]. The optimization plan provided by the APP will refer to the internet database and take account of a set of the best improvement blocks through tested algorithms.

Both of the intelligent feedback of the system and the optimization plan are dynamic according to time and users' regions. Like in USA, the power supply is enough and the power price is much cheaper compared to China, so that the relevant parameters could be different.

## 4. Conclusion

This paper summarizes the research progress of energy visualization systems and related work. Several research projects in different countries have made a concrete analysis. According to the real-time effect of these projects, this paper puts forward a new visualization program which includes intuitive display of energy data at home, interactive control through APP, and optimization plans for users' references.

However, this work needs to be truly developed. By now, it is just a framework. In the future, there will be more work to be done to realize what we describe here.

## References

[1] Jiri Hosek, Pavel Masek, Dominik Kovac, Michal Ries .Universal Smart Energy Communication Platform. *Proceedings of 2014 International Conference on Intelligent Green Building and Smart Grid,* 2014.

[2] Ali Safdar,Kim Dohyeun.Visualization methodology of power consumption in homes. *ICOSST 2013 - 2013 International Conference on Open Source Systems and Technologies*, *Proceedings;*2013 :55-59.

[3] U.S. DoE Energy Efficiency and Renewable Energy, Centerpoint Energy and U.S. Deputy Secretary of Energy Daniel Poneman Announce Results of Pilot Project on Home Energy Use, 2011. [Online]. Available: http://apps1.eere.energy.gov/news/progress\alerts.cfm/pa\id=580.

[4] IBM, "IBM Launches Smarter Energy Cloud in Iowa," 2011. [Online]. Available: http://www-03.ibm.com/press/us/en/pressrelease/35292.wss

[5] Apperley Mark, Kalyan Jishaal.A Mobile Personal Residential Electricity Dashboard. *Proceedings of the International Conference on Information Visualization*. 2015, 9(18): 195-199.

[6] EnerNex Corporation, "Green Button," 2012. [Online]. Available: http://www.greenbuttondata.org

[7] Google Inc., "Google PowerMeter," 2011. [Online]. Available:http://www.google.com/powermeter

[8] Meliones Apostolos,Giannakis Dimitrios.Visual programming of an interactive smart home application using LabVIEW. *IEEE International Conference on Industrial Informatics (INDIN)*, *Proceedings,* 2013, 655-660.

[9] Ghidini Giacomo,Das Sajal K, Gupta Vipul. Fuseviz: A framework for web-based data fusion and visualization in smart environments.*MASS 2012 - 9th IEEE International Conference on Mobile Ad-Hoc and Sensor Systems.*2012, 468-472.

[10] Karnouskos Stamatis.Smart houses in the smart grid and the search for value-added services in the cloud of things era. *Proceedings of the IEEE International Conference on Industrial Technology.*2013, 2016-2021.

[11] Nakazawa Fumihiko, Soneda Hiromitsu, Tsuboi Osamu. Smart power strip network and visualization server to motivate energy conservation in office. *IEEE International Conference on Industrial Informatics (INDIN).*2011, 352-357.

[12] Zucker Gerhard,Habib Usman,Blochle Max. Building energy management and data analytics. *Proceedings - 2015 International Symposium on Smart Electric Distribution Systems and Technologies,* EDST 2015, 462-467.

[13] Zabkowski Tomasz,Gajowniczek Krzysztof,Szupiluk Ryszard.Grade analysis for energy usage patterns segmentation based on smart meter data. *Proceedings - 2015 IEEE 2nd International Conference on Cybernetics,* CYBCONF 2015, 234-239.