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2013-01-31
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Smart Sockets: An enabling system for domestic consumer based demand – response electrical energy management programs

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A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfillment of the requirements for the degree of Masters of Science in Engineering.

DECLARATION

I declare that this dissertation is my own unaided work, except where otherwise acknowledged. It is being submitted for the Degree of Masters of Sciences in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

Signed this ……day of……2012

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ABSTRACT

Electrical energy demand in developing countries is expected to rise significantly by the year 2020. To achieve electrical grid operational reliability the electrical grid operators need to keep a balance between their generation and consumption curve. The increase in demand requires expansion in the current generation capacity. This expansion can be achieved by bringing more green and renewable electrical energy generation resources into the electrical grid system. Keeping the electrical generation and distribution system in stable form at all times is a very complex task. Electricity utilities need to keep a balance between generation and consumption curves in order to achieve reliable grid operations. Grid operators have used many techniques to achieve reliability in grid operations. Demand-side management and demand response strategies are examples of a few of those techniques. "Smart grid" is the overall solution of most of these problems. However, smart grid has its own pros and cons. On the other hand, electrical energy consumers at present are not actively participating in the operations of electrical grids. This lack of participation is both in developed and developing countries. Research has shown that benefits were achieved when electrical energy consumers participated in the electrical grid operations. Grid operators in the past have used different demand response strategies to minimize this gap of interaction between the electrical energy consumers and electricity utilities. Demand response programs or strategies used at present are predominantly for commercial or large electrical energy consumers. There are very few of the demand response strategies deployed for domestic electrical energy consumers. All the present demand response strategies are utility-based strategies, that is electricity utilities have full control over a domestic consumer's electrical energy consumption. When required utilities can switch the appliance ON or OFF in a domestic consumer's household. This utility driven strategy can result in consumer's dissatisfaction. Utilities need to offer demand response programs for the domestic electrical energy consumers. However offering consumer based demand response programs require the active participation from the consumer's side. Electricity utilities must provide their consumers with the information about their electrical energy consumption in real-time. This requires equipment that can monitor electrical energy consumption in real-time and send it back to the utility and the consumer. Smart meters have been used to serve the purpose, however they have their problems. The domestic consumer needs to be onsite (at his home) in order to benefit from the information displayed on a smart meter. Since domestic consumers are not at home at all times the information displayed on the smart meter is not useful. This makes the use of smart meters inefficient. This dissertation proposes a system based on the concept of smart power sockets which can be used at a domestic electrical energy consumer's household in order to monitor their electrical energy in real-time and alert them about their electrical energy consumption when required. These smart power sockets also enable the consumers to control their appliance remotely (to switch them ON or OFF when required). The prototype system has been developed and tested. The results suggest

that domestic electrical energy consumers reacted to the information provided to them about their electrical energy information. Based on the information provided the domestic electrical energy consumer was able to reduce his/her electrical energy consumption. In some cases it is also noticed that the domestic electrical energy consumer shifted some of his/her load from peak time of electrical energy demand to the off peak time. Based on these results it is recommended that electricity utilities must consider offering demand response programs that are mainly driven by the domestic electrical energy consumers themselves.

To GOD Almighty

And

My Parents

ACKNOWLEDGEMENT

I would like to thank following people:

- Prof Barry Dwolatzky, my supervisor, for his guidance and support.
- Prof Rex Van Olst, head of the Center for Telecommunications Access and Services, for his help and support.
- Dr. Muhammad Salman Aslam Minhas for being my role model and inspirational personal throughout my research work.
- Ryan van den Bergh, and colleagues at CeTAS, for their advice and encouragement.

This work was performed in the Wits University Convergence Lab, Centre for Telecommunications Access and Services, at the University of the Witwatersrand, Johannesburg. The Centre is funded by Telkom SA Limited, Nokia-Siemens Networks, Telsaf Data, Vodacom SA (Pty) Ltd, and the Department of Trade and Industry's THRIP programme. Their financial support is greatly appreciated.

PUBLISHED WORK

1. Conference Papers

- Demand-Side Energy Management Performed Using Direct Feedback via Mobile Systems: Enables Utilities to Deploy Consumer Based Demand Response Programs, in proceedings of *IEEE Energy Conference and Exhibition, ENERGYCON 2010,* Bahrain. (Paper No. 1569329467)
- Electrical Energy Consumption Awareness Campaign: Automated Electricity Energy Consumption Monitoring Project at University of the Witwatersrand, Johannesburg, in proceedings of Southern African Telecommunication Networks and Applications Conference (*SATNAC 2010*), Spier Estate, South Africa.
- Smart Demand-Side Energy Management Based on Cellular Technology - A way towards Smart Grid technologies in Africa and Low Budget Economies, in proceedings of *9th IEEE AFRICON 2009*, Nairobi, Kenya. (Paper No.181)
- Direct Feedback Based on Cellular Technology to Support Demand-Side Energy Management, in proceedings of Southern African Telecommunication Networks and Applications Conference (*SATNAC 2009*), Royal Swazi Spa, Swaziland. (Paper No.113)