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DOMESTIC GRID-FRIENDLY APPLIANCE CONTROLLER WITH DEMAND RESPONSE FOR UNDERFREQUENCY LOAD SHAVING

ABUBAKAR KAIGAMA, MUAWIYA

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By

ABUBAKAR KAIGAMA, MUAWIYA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

May 2016

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DEDICATION

Dedicated to my wife Rukaiya M. and my daughter Nana M.K.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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May 2016

Chairman : Noor Izzri Abdul Wahab, PhD
Faculty : Engineering

The smart grid has modified and upgraded the existing traditional grid, these modifications solve lots of shortcomings of the existing traditional grid in terms of energy generation and utilization, it also provides a platform for researchers to ponder on. Among the modifications include adaptive and computational intelligence, improved automation, clean energy integration, 2-way communication and energy flow, improved security, reliability, and end-user conveniences. The traditional grid approach of restoring stability when all measures are exhausted is the conventional load shedding way. However, this type of load shedding subject end-users connected to the affected bus to experience a blackout and absolute discomfort. The smart grid in its early quest to optimize load shedding proffer adaptive and computational schemes which still performs below par. Demand Side Load Management (DSLM) provides a better means of mitigating load shedding than the latter, it also minimizes CO_2 emission contributed by fossil fuel turbines and maximizes energy utilization. Domestic Grid-Friendly Appliance Controller (DG-FAC) is one of the contenders in DSLM, it provides support to grid stability and overcomes the bottleneck of 2-way communication in smart grid realization. DG-FAC manage Grid Friendly Appliance (GFA) loads autonomously based on frequency stability levels of the single-phase voltage, it also automates home surrounding security lightings control to optimum operational hours. The research work conducted involves design and hardware implementation of DG-FAC; this encompasses User Demand Response (UDR), frequency stability sensor and illuminance sensor as the input unit to the system and built on MXP connector “A” of myRIO-1900 module whereas embedded coding utilizing Field Programmable Gate Array (FPGA) personality of myRIO in LabVIEW was developed as the processing unit, and a driver circuit to Solid State Relays (SSR) was built on MXP connector “B”. The SSR controls the flow of supply to GFA loads by sending digitals signal which depends on frequency level and UDR. The design was simulated in LabVIEW and Multisim and then implemented on a hardware platform. The test result signifies that the implementation DG-FAC hardware is feasible. DG-FAC shaves two HVAC loads in the Stage-I and three in Stage-II but cannot support any further after these stages. The simulation of aggregated DG-FAC of one hundred smart homes connected to the same bus indicates that DG-FACs can act as spin reserve (SR), and may provide flexible SR of 24.35% to 42.19% of active loadings between

Stage-I and Stage-II respectively, this will avert any conventional load shedding that may require shedding of active loading between 24.35% to 42.19% in similar scenario with little or no inconveniences by virtue flexible UDR freedom, and hence improves system security. The implementation of DG-FAC showcase a new paradigm of detecting frequency instability via LabVIEW real-time, adds to the number of few existing GFA controller hardware, improves GFA utilization with daily activities of lighting automation, and provide a platform for a flexible open-ended design utilizing FPGA and LabVIEW capabilities which include parallelism of executing task.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

GRID MESRA PENGAWAL PERKAKAS DENGAN TINDAK BALAS PERMINTAAN UNTUK FREKUENSI DIBAWAH BEBAN MENCUKUR

Oleh

ABUBAKAR KAIGAMA, MUAWIYA

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Grid pintar telah diubahsuai dan dinaik taraf dari grid tradisional yang sedia ada, dimana pengubahsuaian ini dapat mengatasi banyak kelemahan grid sedia ada dari segi penjanaan tenaga dan pemanfaatannya, ia juga menyediakan landasan untuk para penyelidik menjalankan kajian. Antara pengubahsuaian yang dilakukan termasuklah penyesuaian dan kecerdasan komputasi, memperbaiki automasi, persepaduan tenaga bersih, komunikasi dan aliran tenaga dua hala, meningkatkan tahap keselamatan, kebolehpercayaan, dan kemudahan untuk pengguna akhir. Grid tradisional menggunakan pendekatan pemulihan kestabilan apabila semua bahagian telah kehilangan upaya dan ini adalah merupakan pelepasan beban konvensional. Walaubagaimanapun, jenis pelepasan beban ini tertakluk kepada pengguna akhir yang berhubung dengan bas yang terjejas dan mengalami penggelapan dan ketidakselesaan mutlak. Di awal kajian, grid pintar adalah untuk mengoptimumkan pelepasan beban yang menunjukkan penyesuaian dan skim komputasi yang mana masih dilakukan dibawah par. Pengurusan pada sisi permintaan beban (DSLM) menyediakan cara yang lebih baik untuk mengurangkan pelepasan beban berbanding cara satu lagi, dan ia juga mengurangkan pelepasan karbon dioksida (CO_2) yang disumbangkan oleh turbin bahan bakar fosil dan memaksimumkan penggunaan tenaga. Pengawal perkakas grid mesra domestik (DG-FAC) adalah salah satu pesaing dalam DSLM, ia juga menyediakan sokongan kepada kestabilan grid dan mengatasi masalah kesesakan komunikasi dua hala dalam pelaksanaan grid pintar. DG-FAC menguruskan beban perkakas grid mesra (GFA) secara persendirian berdasarkan pada aras kestabilan frekuensi pada voltan fasa tunggal, ia juga mengautomasikan kawalan lampu keselamatan di persekitaran rumah kepada masa operasi yang optimum. Kerja–kerja penyelidikan yang dijalankan melibatkan rekaanbentuk dan pembangunan perkakasan DG-FAC, ia merangkumi tindak balas permintaan pengguna (UDR), sensor kestabilan frekuensi dan sensor cahaya siang sebagai unit masukan sistem dan dibina pada penyambung MXP "A" pada modul myRIO-1900, manakala pengkodan menggunakan personaliti myRIO lapangan terpogram gerbang logika (FPGA) dalam LabVIEW dibangunkan sebagai unit pemprosesan, dan litar pemacu kepada geganti padat (SSR)dibina pada penyambung MXP "B". SSR mengawal aliran bekalan kuasa kepada beban GFA dengan menghantar isyarat digital yang mana bergantung kepada aras frekuensi dan UDR. Rekaan tersebut disimulasi dalam perisian LabVIEW dan Multisin dan

direalisasikan kepada lapangan perkakasan. Keputusan ujian menunjukkan bahawa pelaksanaan perkakasan DG-FAC adalah wajar, DG-FAC mencukur dua beban HVAC semasa tahap I dan tiga pada tahap II tetapi ia tidak dapat menampung apa-apa lagi selepas tahap tersebut. Pengumpulan hasil simulasi DG-FAC untuk seratus buah rumah pintar yang dihubungkan kepada bas yang sama menunjukkan bahawa ia boleh bertindak sebagai cadangan putar (SR), dan boleh menyediakan SR fleksibel antara 24.35 % sehingga 42.19 % beban aktif diantara tahap I dan tahap II setiap satu. Ini dapat mengelakkan berlaku pelepasan beban konvensional yang mungkin dilepaskan ketika bebanan aktif antara 24.35 % sehingga 42.19 % dalam senario yang sama dengan gangguan yang sedikit atau tiada oleh pembebasan UDR fleksibel, maka ia telah menambahbaik sistem keselamatan. Pelaksanaan DG-FAC menunjukkan paradigm baru dalam mengesan frekuensi tidak stabil melalui penggunaan LabVIEW masa sebenar, penambahan angka jumlah perkakasan pengawal GFA sedia ada, penambahbaikan penggunaan GFA dalam kehidupan harian melalui automasi pencahayaan, dan menyediakan lapangan untuk rekaan fleksibel terbuka menggunakan FPGA dan LabVIEW selari dengan kehendak tugasan.

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I certify that a Thesis Examination Committee has met on 17 May 2016 to conduct the final examination of Abubakar Kaigama, Muawiya on his thesis entitled "Domestic Grid-Friendly Appliance Controller with Demand Response for Underfrequency Load Shaving" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded degree of Master of Science.

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Committee: ________________________________

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LIST OF ABBREVIATIONS

CPP	Critical Peak Pricing
CU	Consumer Unit
DB	Distribution Board
DER	Distributed Energy Resources
DG-FAC	Domestic Grid-friendly Appliance Controller
DIO	Digital Input/output
DI	Digital Input
DLC	Direct Load Control
DO	Digital Output
DR	Demand Response
DSLM	Demand Side Load Management
FCDM	Frequency Control Demand Management
GFA	Grid-Friendly Appliance
HEM	Home Energy Management
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
LVTTL	Low Voltage Transistor-Transistor Logic
myRIO-1900	My Reconfigurable Input/output model 1900
MXP	MyRIO-1900 Expansion Port
RES	Renewable Energy Sources
RTP	Real-Time Pricing
SLS	Smart Load Shaving
SR	Spinning Reserve
TNB	Tenaga Nasional Berhad

ToU	Time of Use
UDR	User Demand Response
UI	User Interface
SPST	Single Pole Single Throw
SSR	Solid State Relay

CHAPTER 1

INTRODUCTION

This chapter presents the research background, targets, and objectives. It further highlights a general overview of the thesis on the research findings and expectations. The chapter aims at enhancing the reader's knowledge towards understanding the research expected outcome, and why the research was conducted.

1.1 Background of the Study

The existing electrical grid system has been in existence for over a century and has been serving the purpose of electrical energy generation, transmission, and distribution as a robust system (Solé, Rosas-Casals, Corominas-Murtra, & Valverde, 2008). Although the current state of art in electrical power of the 21st century is putting more efforts in upgrading and optimizing the existing grid system's operation, and this new system is a hot topic in the area of research and is termed smart grid (Bera, Misra, & Rodrigues, 2015; Wang, Wang, & Liang, 2010).

1.1.1 Electrical Power and Energy Management

The electrical power grid has been the primary global source of electrical energy for decades and considered the robust system that ever existed in history (Cunjiang, Huaxun, & Lei, 2012; Solé et al., 2008). Stability, reliability, utilization and proper management are some of the features that lead to its robustness. This robustness feature perception serves as a norm in all electrical utilities and is essential for maintaining electrical power grid system's stability, ensure its supply continuity, and also serve as a means of maximizing end-user satisfaction. With the increasing trend in population and technological innovations (Amer, Naaman, Sirdi, M'Sirdi, & El-Zonkoly, 2014; Coley & Lemon, 2009), the power demand by end-users tend towards surpassing the amount generated(Coley & Lemon, 2009), more especially during peak hours (Coley & Lemon, 2009; Madani & King, 2007). Thus, in such scenario, the conventional grid has two measures to counteract such and similar disturbances, this includes building more generating stations or load shedding when necessary and after exhausting all necessary protective and corrective avenues for restoring stability.

The restoration procedure includes self-adjustment of the generator's governor to meet up with frequency and voltage variations in the generating stations, transformer action, capacitor bank operation, redundant /backup power supply, etc. (Sigrist, Egido, & Rouco, 2012). Load shedding serves as the last line of defense for restoring system stability due to fault, disturbance, loss of generation source, or any undesired contributions to the electrical grid that leads to undervoltage and underfrequency situations.

The load shedding of affected buses is triggered by deviations below a nominal threshold values for either frequency or voltage leading to underfrequency or undervoltage respectively (Hooshmand & Moazzami, 2012; Hoseinzadeh, Faria, & Silva, 2014; Tang, Liu, Ponci, & Monti, 2013), these two types of load shedding are accepted global means for measuring instability of generation against the demand of electrical power systems (Ye Li et al., 2014). Conventional load shedding is a welcome idea by utilities since it proffers immediate solution to instability, thereby protecting the system from a total failure and damages due to system overloading or imbalance. However, it is not a welcome idea for the affected end-users connected to the disturbed bus, this causes an absolute denial of the power supply during the disturbance period, leading to consequences of 100% discomfort and several losses. The mode of operation of conventional load shedding may be seen as injustice because the affected end-users are disconnected from the power supply even though they are willing to pay for services at all times. Whereas other end-users connected to the unaffected buses, enjoy full power supply

The shortcomings of the current grid drive researchers to opt for a better grid performance. This challenge gives rise to the evolution of future grid otherwise known as the smart grid; the smart grid refer to as an intelligent power system model that provide solutions to the challenges faced by the conventional grid. It integrates information and communication technology (ICT), intelligence, automation, efficient energy utilization, efficient energy management, efficient green energy generation, reduction of greenhouse gasses, etc. (I. Khan et al., 2013; Shirazi & Jadid, 2015). Unlike in the conventional grid, where only utility is responsible for maintaining system stability and reliability, the smart grid platform enables end-users to contribute their quota to ensuring the stability of the grid. This includes Demand Response (DR), Grid Friendly Appliance (GFA), Home Energy Management (HEM), Smart Load shaving (SLS) at end-users' domain, etc. which act as Spinning Reserves (SR).

Renewable Energy Resources (RES) injection to the grid and load-shifting toOff-Peak periods also contribute to maintaining grid stability. However, all these aspects are lagging in the conventional grid system. These smart home features mitigate the impact of conventional load shedding via load shaving that averts load shedding to an extent, this act invariably increases the comfort zone of end-users via load shaving house demand with little or no discomfort during disturbance situations.

The research findings of this work focus on hardware realization of versatile improved Domestic Grid-Friendly Appliance Controller (DG-FAC). However, the question is: what is DG-FAC and how does it operate?

DG-FAC is an autonomous hardware system installed in a smart home for the purpose of enhancing grid stability and mitigating traditional load shedding effect with SLS. The target is achievable by maximizing end-user convenience with a flexible and easy-to-use UDR provision that is accessible to the end-user for selection of GFA of choice to be turned OFF when the need arises. It also turns ON the GFA supply when the system stabilizes.
DG-FAC is a decentralized controller that detects system's stability threat by sensing

frequency deterioration from nominal set-threshold (underfrequency), this frequency deviation is perceived as DR to restore system's stability. Therefore, the DG-FAC perform adaptive load shaving while considering end-user load priorities and also restore the load in two stages based on system frequency states. Since disturbance rarely occurs on robust systems with large operating reserves, the DG-FAC will be redundant most of the times. Hence, Home Energy Management (HEM) component of outdoor lighting automation is incorporated to maximize DG-FAC with daily activities of lighting automation, this optimizes the operation time and hence reduces unnecessary electricity consumption.

1.1.2 An Overview of Smart Grid Topology

The Smart Grid is the state-of-art electrical grid network, it has advanced and improved features over the conventional grid that includes the 2-way flow of energy and 2-way flow of communication between utility and end users. It upgrades the existing electrical grid with more renewable energy sources (RES) and efficient way of maximizing the available energy in all its domains. Figure 1.1 shows a typical basic topology of a smart grid network (von Dollen, 2009).

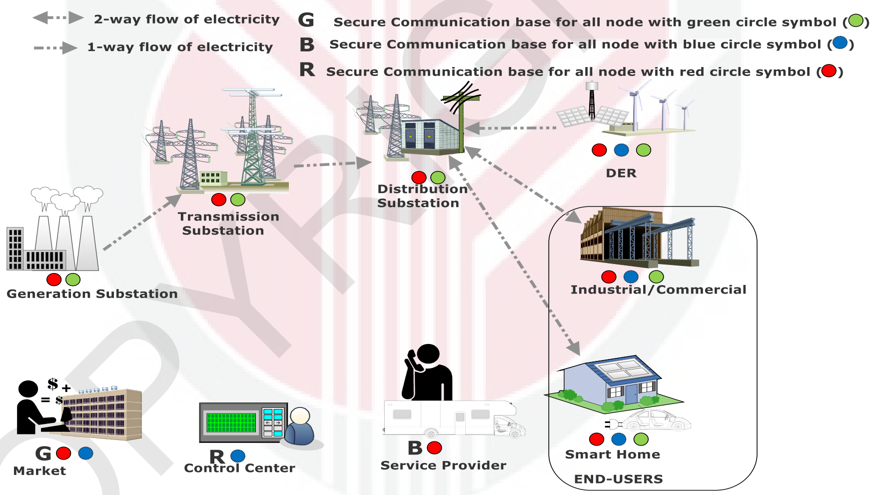

Figure 1.1: Typical topology of smart grid network

A typical smart grid has eight domains, the interconnection of flow of energy and communication between the eight domains and also an additional domain of DER is shown in Figure 1.1, and the brief role of each of these domains forming smart grid network is stated in Table 1.1. Each domain has a primary role to perform in the network and considered as a vital component forming the network.

1.2 Problem Statement

The ratio of demand to generation is growing in favor of demand (Aponte, Member, & Nelson, 2006; Tsado, Lund, & Gamage, 2014) due development and addition of new end-users (V. C. Gungor et al., 2011). This may lead to peak loading and imbalance thereby subjecting electrical grid to instability (Amer et al., 2014). Majority of Conventional grid systems employ coal and gas generating stations in generating electrical energy, this type generating stations contributes the highest quota in electric power production (Y. Chang, Huang, Ries, & Masanet, 2015; W. Han, Jin, & Lin, 2011), and are considered as some of the major contributors to air pollution via CO2 emission and also increases global warming (Varaiya, Wu, & Bialek, 2011).

Table 1.1: Smart grid domains

S/N	Domain	Role in the grid network
1	**Generation Substation**	**Primary source of electricity generation to the grid**
2	**Transmission Substation**	**Receives electricity from generating station and transmits to distribution stations**
3	**Distribution Substation**	**Receives electricity from transmission station and distributes to end user**
4	**DER**	**Secondary source of electricity generation to the grid via RES**
5	**End Users**	**Consumers of electricity and some cases tertiary sources of electricity generation to the grid**
6	**Service Providers**	**Organization(s) that are responsible for providing services such as the internet to Utility and end-users**
7	**Control Center**	**Manages the flow of electricity in the grid network**
8	**Market**	**These are operators and participants that That interact with dynamic prices to control supply vs. demand curve.**

Source: (von Dollen, 2009)

The existing electrical grid system resorts to load shedding as the last shedding action leads to 0% power supply, 100% end-user discomfort regarding electricity supply and lots of losses. Meanwhile, the domestic end-users would have contributed in the DSLM if considered. However, existing electricity grid has DSLM programs only for medium voltage end-users such as industries and commercial settings and reward them with incentives and rebates to DSLM whereas the domestic consumer is deprived of these benefits (A. A. A. Khan et al., 2015).

The evolution of smart grid initiatives seems to provide a solution to this challenges, but its dependence on 2-way communication may be hampered by significant disturbances, signal interference, and signal attenuation such as natural disasters or communication failure (V. C. V. C. Gungor et al., 2011). Hence, the need for a system that can detect disturbance without reliance on 2-way communication is essential. In the quest for smart grid realization, the transformation of the existing grid components by upgrading them to be smart grid compliant will minimize cost of smart grid realization while compl

The end-users in the smart home are vying for the more robust power system, better means of saving electrical and physical energy at homes via increase home automation while retaining their comfort level and priorities at all times (Anvari-Moghaddam, Monsef, & Rahimi-Kian, 2015).

1.3 Objectives of the Study

Main:

i. To design DG-FAC with UDR capable of performing autonomous underfrequency load shaving with little or no end-user discomfort.
ii. To develop and implement the hardware of the DG-FAC system.

Sub:

To design and implement an autonomous smart home outdoor lighting control system and be integrated into the DG-FAC.

1.4 Scope and Limitation of Research

i. The DG-FAC is designed and developed for domestic application only.
ii. The DG-FAC is designed to accommodate single phase, 230VAC, 50Hz from a single phase supply.
iii. The DG-FAC is designed to carry loads rated between 1hp – 6hp and not exceeding 80A capacity.
iv. The DG-FAC act as a load supply controller and not a circuit breaker

1.5 Hypothesis

i. DG-FAC improves grid system stability by turning OFF individual loads when the grid system is subjected to disturbance. The DG-FAC also restores loads to ON state when the system stabilizes autonomously.
ii. The UDR increases end-user comfort zone and flexibility of load shaving based on preferred loads of choice at any time to a large extent.

iii. The smart home autonomous outdoor lighting control saves the end-user energy of controlling lights and reduces electricity bill due to negligence or oversight in turning OFF lights at an optimal time.

1.6 Contributions to Knowledge

i. The new paradigm of detecting power instability via automatic underfrequency sensor using LabVIEW coding.
ii. Hardware development of DG-FAC whereas the majority of the previous findings bases on simulations only (Bao & Li, 2014).
iii. Versatile GFA with the aid of FPGA enables the design to be open-ended and flexible, and the incorporation of autonomous security light control maximizes the GFA utilization.

1.7 Organization of Thesis

This Thesis encompasses of five chapters. Chapter 2 review relevant finding in related research areas and their contributions to the field of study. Chapter 3 analyzes the stages of the design and development of DG-FAC including the software and the hardware aspects. Chapter 4 discuss the result obtained, and Chapter 5 concludes with the overall findings, recommends on possible ways of furthering the research to enhance its quality, ensure its continuity and transparency as well.

1.8 Summary

This chapter aims at introducing the essence of performing the research in context to existing findings and also its importance, it further gives an insight of the target set and the expected result to solve existing problems, as well as measures on how to improve power stability and reliability in the smart grid way. Meanwhile, the design limitations elaborate more on expected product; DG-FAC is hypothesized to give the end-user of electrical energy a more comfortable lifestyle with economic benefits. The layout set for achieving the set target was also discussed in this section. An overview of typical smart grid structure was further illustrated to show a clear picture of the future electrical grid directions.

REFERENCES

74hc14n datasheet. (2002). Retrieved February 3, 2016, from www.ti.com/lit/ds/symlink/sn74hc14.pdf

Amer, M., Naaman, A., Sirdi, N. K. M., M'Sirdi, N. K., & El-Zonkoly, A. M. (2014). A Hardware Algorithm for PAR Reduction in Smart Home. In *IEEE 12th International Conference on Applied and Theoretical Electricity, ICATE* (pp. 1–6). IEEE. http://doi.org/10.1109/ICATE.2014.6972615

Anandalakshmi, T. K., Sathiakumar, S., & Parameswaran, N. (2014). Policy-Based Energy Management in Smart Homes. In S. Sathiakumar, L. K. Awasthi, M. R. Masillamani, & S. S. Sridhar (Eds.), (Vol. 216, pp. 9–23). New Delhi: Springer India. Retrieved from http://ezproxy.upm.edu.my:2135/chapter/10.1007/978-81-322-1299-7_2

Andersson, G., Donalek, P., Farmer, R., Hatziargyriou, N., Kamwa, I., Kundur, P., … Vittal, V. (2005). Causes of the 2003 major grid blackouts in North America Europe, and recommended means to improve system dynamic performance. *IEEE Transactions on Power Systems*, *20*(4), 1922–1928. http://doi.org/10.1109/TPWRS.2005.857942

Anvari-Moghaddam, A., Monsef, H., & Rahimi-Kian, A. (2015). Optimal Smart Home Energy Management Considering Energy Saving and a Comfortable Lifestyle. *IEEE Transactions on Smart Grid*, *6*(1), 324–332. http://doi.org/10.1109/TSG.2014.2349352

Aponte, E. E., Member, S., & Nelson, J. K. (2006). Time Optimal Load Shedding for Distributed Power Systems. *IEEE Trans Power Syst*, *21*(1), 269–277.

Ashraf, H., Hassan, A., Khurshid, U., Mahmood, A., Shaheen, N., Khan, Z. A., … Javaid, N. (2015). Peak Load Shaving Model Based on Individual's Habit. In *IEEE 9th International Conference on Complex, Intelligent, and Software Intensive Systems (CISIS-2015)* (pp. 276–282). Blumenau, Brazil.: IEEE. http://doi.org/10.1109/CISIS.2015.94

Azab, R. M. El, & Lataire, P. (2010). Simulation Programs for Load Shedding Studies : Expermintal Results, *11*(6), 61–66.

Bao, Y. Q., & Li, Y. (2014). FPGA-based design of grid friendly appliance controller. *IEEE Transactions on Smart Grid*, *5*(2), 924–931. http://doi.org/10.1109/TSG.2013.2285178

Bera, S., Misra, S., & Rodrigues, J. J. P. C. (2015). Cloud Computing Applications for Smart Grid: A Survey. *IEEE Transactions on Parallel and Distributed Systems*, *26*(5), 1477–1494. http://doi.org/10.1109/TPDS.2014.2321378

Chai, B., Chen, J., Yang, Z., & Zhang, Y. (2014). Demand response management with multiple utility companies: A two-level game approach. *IEEE Transactions on Smart Grid*, *5*(2), 722–731. http://doi.org/10.1109/TSG.2013.2295024

Chang, T.-H., Alizadeh, M., & Scaglione, A. (2013). Real-Time Power Balancing Via Decentralized Coordinated Home Energy Scheduling. *IEEE Transactions on Smart Grid*, *4*(3), 1490–1504. http://doi.org/10.1109/TSG.2013.2250532

Chang, Y., Huang, R., Ries, R. J., & Masanet, E. (2015). Life-cycle comparison of greenhouse gas emissions and water consumption for coal and shale gas fi red power generation in China. *Energy*, *86*, 335–343. http://doi.org/10.1016/j.energy.2015.04.034

Chang-Chien, L.-R. R., An, L. N., Lin, T.-W. W., & Lee, W.-J. J. (2012). Incorporating demand response with spinning reserve to realize an adaptive frequency restoration plan for system contingencies. *IEEE Transactions on Smart Grid*, *3*(3), 1145–1153. http://doi.org/10.1109/TSG.2012.2192297

Chaudhari, R. B., Dhande, D. P., & Chaudhari, A. P. (2014, July 8). Home Energy Management System. *International Journal of Advanced Electronics and Communication Systems*. Retrieved from http://www.techniche-edu.in/journals/index.php/ijaecs/article/view/164

Coley, F. J. S., & Lemon, M. (2009). Exploring the design and perceived benefit of sustainable solutions: a review. *Journal of Engineering Design*, *20*(6), 543–554. http://doi.org/10.1080/09544820802001276

Cunjiang, Y., Huaxun, Z., & Lei, Z. (2012). Architecture Design For Smart Grid. *Energy Procedia*, *17*, 1524–1528. http://doi.org/10.1016/j.egypro.2012.02.276

Dänekas, C., Neureiter, C., & Rohjans, S. (2014). Towards a model-driven-architecture process for smart grid projects. *Digital Enterprise Design …*. Retrieved from http://link.springer.com/chapter/10.1007/978-3-319-04313-5_5

Duffy, C. (2010). Blackout watch. *Protection, Automation & Control World*, *3*, 34–35.

Ela, E., Milligan, M., & Kirby, B. (2011). Operating Reserves and Variable Generation. *Contract*, (August), 1–103. http://doi.org/10.2172/1023095

Eng, J. H. B. (2009). The Development , Implementation , and Application of Demand Side Management and control (DSM + c) Algorithm for Integrating Micro- generation System within Built Environment. *Mechanical Engineering*, (March), 273.

Fahrioglu, M., & Alvarado, F. L. (2000). Designing incentive compatible contracts for effective demand management. *IEEE Transactions on Power Systems*, *15*(4), 1255–1260. http://doi.org/10.1109/59.898098

Fairbanks AK, Anchorage AK, and R. W. (2008). Average Power Consumption of Household Appliances | Alternative & Renewable Energy - ABS Alaskan, Inc. Retrieved January 28, 2016, from http://www.absak.com/library/power-consumption-table

Fan, Z., Kulkarni, P., Gormus, S., Efthymiou, C., Kalogridis, G., Sooriyabandara, M., … Chin, W. H. (2013). Smart Grid Communications: Overview of Research Challenges, Solutions, and Standardization Activities. *IEEE Communications Surveys & Tutorials*, *15*(1), 21–38. http://doi.org/10.1109/SURV.2011.122211.00021

Faruqui, A., Hledik, R., & Tsoukalis, J. (2009). The Power of Dynamic Pricing. *The Electricity Journal*, *22*(3), 42–56. http://doi.org/10.1016/j.tej.2009.02.011

Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. (2011). Smart Grid Technologies: Communication Technologies and Standards. *IEEE Transactions on Industrial Informatics*, *7*(4), 529–539. http://doi.org/10.1109/TII.2011.2166794

Gungor, V. C. V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. G. P. (2011). Smart Grid Technologies: Communication Technologies and Standards. *IEEE Transactions on Industrial Informatics*, *7*(4), 529–539. http://doi.org/10.1109/TII.2011.2166794

Hammerstrom, D. J. (2006). Design Considerations for Frequency Responsive Grid Friendly Appliances. In *2005/2006 PES TD* (pp. 647–652). IEEE. http://doi.org/10.1109/TDC.2006.1668573

Hammerstron, D. (2007). Part II: Grid Friendly™ Appliance Project of the Pacific Northwest GridWise™ Testbed Demonstration Projects. *PNNL-17079). Richland, WA: DOE, PNNL, Gridwise*. Retrieved from https://scholar.google.com/scholar?start=20&q=%22grid+friendly+appliance%22&hl=en&as_sdt=0,5#2

Han, D.-M., & Lim, J.-H. (2010a). Design and implementation of smart home energy management systems based on zigbee. *IEEE Transactions on Consumer Electronics*, *56*(3), 1417–1425. http://doi.org/10.1109/TCE.2010.5606278

Han, D.-M., & Lim, J.-H. (2010b). Smart home energy management system using IEEE 802.15.4 and zigbee. *IEEE Transactions on Consumer Electronics*, *56*(3), 1403–1410. http://doi.org/10.1109/TCE.2010.5606276

Han, W., Jin, H., & Lin, R. (2011). A novel power generation system based on moderate conversion of chemical energy of coal and natural gas. *Fuel*, *90*(1), 263–271. http://doi.org/10.1016/j.fuel.2010.09.005

Hong, Y. Y., & Chen, P. H. (2012). Genetic-based underfrequency load shedding in a stand-alone power system considering fuzzy loads. *IEEE Transactions on Power Delivery*, *27*(1), 87–95. http://doi.org/10.1109/TPWRD.2011.2170860

Hooshmand, R., & Moazzami, M. (2012). Optimal design of adaptive under frequency load shedding using artificial neural networks in isolated power system. *International Journal of Electrical Power & Energy Systems*, *42*(1), 220–228. http://doi.org/10.1016/j.ijepes.2012.04.021

Hoseinzadeh, B., Faria, F., & Silva, D. (2014). Power System Stability Using Decentralized Under Frequency and Voltage Load Shedding. In *PES General Meeting* (pp. 1–5). National Harbor, MD: IEEE. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6939306

Hoseinzadeh, B., Faria, F., Silva, D., Faria Da Silva, F., Bak, C. L., Faria, F., & Silva, D. (2014). Power System Stability Using Decentralized Under Frequency and Voltage Load Shedding. In *2014 IEEE PES General Meeting | Conference & Exposition* (pp. 1–5). National Harbor, MD: IEEE. http://doi.org/10.1109/PESGM.2014.6939306

Hsu, C., Kang, M., & Chen, C. (2005). Design of adaptive load shedding by artificial neural networks. *Generation, Transmission and …*. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1453836

IEC - Smart Grid Core Standards. (1998). Retrieved October 26, 2015, from http://www.iec.ch/smartgrid/standards/

Kaliappan, A. T., Sathiakumar, S., & Parameswaran, N. (2012). Flexible power consumption management in smart homes. In *Proceedings of the International Conference on Advances in Computing, Communications and Informatics - ICACCI '12* (p. 161). New York, New York, USA: ACM Press. http://doi.org/10.1145/2345396.2345424

Kay, A. (2015). TI Designs – Precision : Verified Design Instrumentation Amplifier with DC Rejection Reference Design Measured vs . Simulated Freq . Response (pp. 1–15).

Khan, A. A. A., Razzaq, S., Khan, A. A. A., Khursheed, F., Owais, Ahmed, A., … Khursheed, F. (2015). HEMSs and enabled demand response in electricity market : An overview. *Renewable and Sustainable Energy Reviews*, *42*(0), 773–785. http://doi.org/10.1016/j.rser.2014.10.045

Khan, I., Javaid, N., Ullah, M. M. N. N., Khan, I., Ullah, M. M. N. N., Mahmood, A., & Farooq, M. U. U. (2013). A Survey of Home Energy Management Systems in Future Smart Grid Communications. *2013 Eighth International Conference on Broadband and Wireless Computing, Communication and Applications*, 459–464. http://doi.org/10.1109/BWCCA.2013.80

Kim, Y.-J., Yang, K., & Thottan, M. (2011). Cloud-based demand response for smart grid: Architecture and distributed algorithms. In *2011 IEEE International Conference on Smart Grid Communications (SmartGridComm)* (pp. 398–403). IEEE. http://doi.org/10.1109/SmartGridComm.2011.6102355

Kirby, B., & Ally, M. (2002). Spinning reserve from supervisory thermostat control. *… Reliability Research Review. Washington DC: US …*. Retrieved from https://scholar.google.com/scholar?hl=en&q=Spinning+Reserve+from+Supervisory+Thermo-stat+Control&btnG=&as_sdt=1%2C5&as_sdtp=#0

Kühner, J. (2009). Chapter 7 - Wireless Communication (pp. 203–217). Apress. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4302-2388-7_7

Kuzlu, M., Pipattanasomporn, M., & Rahman, S. (2012). Hardware Demonstration of a Home Energy Management System for Demand Response Applications. *IEEE Transactions on Smart Grid*, *3*(4), 1704–1711. http://doi.org/10.1109/TSG.2012.2216295

Laghari, J. A. a., Mokhlis, H., Bakar, A. H. A. H. a, & Mohamad, H. (2013). Application of computational intelligence techniques for load shedding in power systems: A review. *Energy Conversion and Management*, *75*(August 2003), 130–140. http://doi.org/10.1016/j.enconman.2013.06.010

Lai, Y.-X., Rodrigues, J. J. P. C., Huang, Y.-M., Wang, H.-G., & Lai, C.-F. (2012). An Intercommunication Home Energy Management System with Appliance Recognition in Home Network. *Mobile Networks and Applications*, *17*(1), 132–142. http://doi.org/10.1007/s11036-011-0345-z

LeMay, M., Nelli, R., Gross, G., & Gunter, C. A. (2008). An Integrated Architecture for Demand Response Communications and Control. In *Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008)* (pp. 174–174). IEEE. http://doi.org/10.1109/HICSS.2008.60

Limbu, T. R., Saha, T. K., & McDonald, J. D. F. (2011). Value-based allocation and settlement of reserves in electricity markets. *IET Generation, Transmission & Distribution*, *5*(4), 489. http://doi.org/10.1049/iet-gtd.2010.0467

LM2901N Datasheet: Single Supply Quad Comparators - ON Semiconductor. (2015). Retrieved January 25, 2016, from http://www.datasheetcatalog.com/datasheets_pdf/L/M/2/9/LM2901N.shtml

Lu, N., Hammerstrom, D. J., & Patrick, S. (2009). *Grid Friendly Device Model Development and Simulation*. Pacific Northwest National Laboratory.

Lu, S., Samaan, N., Diao, R., Elizondo, M., Jin, C., Mayhorn, E., … Kirkham, H. (2011). Centralized and decentralized control for demand response. In *ISGT 2011* (pp. 1–8). IEEE. http://doi.org/10.1109/ISGT.2011.5759191

Madani, V., & King, R. L. (2007). Strategies and Applications to Meet Grid Challenges and Enhance Power System Performance. In *2007 IEEE Power Engineering Society General Meeting* (pp. 1–9). IEEE. http://doi.org/10.1109/PES.2007.386255

Mahmood, A., Javaid, N., & Razzaq, S. (2015). A review of wireless communications for smart grid. *Renewable and Sustainable Energy Reviews*, *41*, 248–260. Retrieved from http://www.sciencedirect.com/science/article/pii/S1364032114007126

Maldonado, G. . (2004). The performance of North American nuclear power plants during the electric power blackout of August 14, 2003 (Vol. 7, pp. 4603–4606 Vol. 7). http://doi.org/10.1109/NSSMIC.2004.1466907

Manson, S., Zweigle, G., & Yedidi, V. (2014). Case Study: An Adaptive Underfrequency Load-Shedding System. *IEEE Transactions on Industry Applications*, *50*(3), 1659–1667. http://doi.org/10.1109/TIA.2013.2288432

Moazzami, M., Hooshmand, R. a, Khodabakhshian, a, & Yazdanpanah, M. (2013). Blackout Prevention in Power System Using Flexible AC Transmission System Devices and Combined Corrective Actions. *Electric Power Components & Systems*, *41*(15), 1433–1455. http://doi.org/10.1080/15325008.2013.830655

Moghadam, M. (2013). Distributed frequency control via demand response in smart grids. *Acoustics, Speech and …*. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6638661

Molina-García, A., Bouffard, F., Kirschen, D. S., Molina-Garcia, A., Bouffard, F., Kirschen, D. S., & Molina-García, A. (2011). Decentralized demand-side contribution to primary frequency control. *IEEE Transactions on Power Systems*, *26*(1), 411–419. http://doi.org/10.1109/TPWRS.2010.2048223

Nagarajan, R., & Dhanasekaran, R. (2013). Implementation of wireless data transmission in monitoring and control (pp. 83–87). http://doi.org/10.1109/iccsp.2013.6577020

Naranjo Palacio, S., Kircher, K. J., & Zhang, K. M. (2015). On the feasibility of providing power system spinning reserves from thermal storage. *Energy and*

Buildings, *104*, 131–138. http://doi.org/10.1016/j.enbuild.2015.06.065

National Instruments. (2013). User guide and specifications NI myRIO-1900.

Niyato, D., Xiao, L., & Wang, P. (2011). Machine-to-machine communications for home energy management system in smart grid. *Communications Magazine, IEEE*, *49*(4), 53–59. Retrieved from http://trafficlight.bitdefender.com/info?url=http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5741146&language=en_US

Off-Peak Tariff Rider | Tenaga Nasional Berhad (200866-W). (2005). Retrieved January 8, 2015, from http://www.tnb.com.my/business/discounts-rebates-offers/off-peak-tariff-rider.html

Ortega-Vazquez, M. A., & Kirschen, D. S. (2007). Optimizing the Spinning Reserve Requirements Using a Cost/Benefit Analysis. *IEEE Transactions on Power Systems*, *22*(1), 24–33. http://doi.org/10.1109/TPWRS.2006.888951

Pavić, I., Capuder, T., & Kuzle, I. (2015). Value of flexible electric vehicles in providing spinning reserve services. *Applied Energy*, *157*, 60–74. http://doi.org/10.1016/j.apenergy.2015.07.070

Pourmousavi, S. a, & Nehrir, M. H. (2012). Real-Time Central Demand Response for Primary Frequency Regulation in Microgrids. *Ieee Transactions on Smart Grid*, *3*(4), 1988–1996. http://doi.org/10.1109/tsg.2012.2201964

Rahmani-andebili, M. (2013). Spinning reserve supply with presence of electric vehicles aggregator considering compromise between cost and reliability. *IET Generation, Transmission & Distribution*, *7*(12), 1442–1452. http://doi.org/10.1049/iet-gtd.2013.0118

Rebours, Y., & Kirschen, D. S. (2005). *A Survey of Definitions and Specifications of Reserve Services. Report, University of Manchester*. Retrieved from http://www.ee.washington.edu/research/real/Library/Reports/Survey_of_Reserve_Services.pdf

Reddy, S. S., Bijwe, P. R., & Abhyankar, A. R. (2015). Joint Energy and Spinning Reserve Market Clearing Incorporating Wind Power and Load Forecast Uncertainties. *IEEE Systems Journal*, *9*(1), 152–164. http://doi.org/10.1109/JSYST.2013.2272236

Saffarian, A., & Sanaye-Pasand, M. (2011). Enhancement of power system stability using adaptive combinational load shedding methods. *IEEE Transactions on Power Systems*, *26*(3), 1010–1020. http://doi.org/10.1109/TPWRS.2010.2078525

Samarakoon, K., & Ekanayake, J. (2009). Demand side primary frequency response support through smart meter control. *Universities Power*

Engineering Conference (UPEC), 2009 Proceedings of the 44th International, 0–4.

Sanaye-Pasand, M., Abedini, M., & Azizi, S. (2014). Adaptive load shedding scheme to preserve the power system stability following large disturbances. *IET Generation, Transmission & Distribution*, *8*(12), 2124–2133. http://doi.org/10.1049/iet-gtd.2013.0937

Sanaye-Pasand, M., & Seyedi, H. (2009). New centralised adaptive load-shedding algorithms to mitigate power system blackouts. *IET Generation, Transmission & Distribution*, *3*(1), 99–114. http://doi.org/10.1049/iet-gtd:20080210

Sergio Franco. (2015). *DESIGN WITH OPERATIONAL AMPLIFIERS AND ANALOG INTEGRATED CIRCUITS*. *Igarss 2014* (4th ed.). McGraw Hill. http://doi.org/10.1007/s13398-014-0173-7.2

Shayesteh, E., Amelin, M., & Soder, L. (2015). Area equivalents for spinning reserve determination in interconnected power systems. *Energy*, *88*, 907–916. http://doi.org/10.1016/j.energy.2015.07.046

Shirazi, E., & Jadid, S. (2015). Optimal Residential Appliance Scheduling Under Dynamic Pricing Scheme via HEMDAS. *Energy and Buildings*, *93*, 40–49. http://doi.org/10.1016/j.enbuild.2015.01.061

Shokri Gazafroudi, A., Afshar, K., & Bigdeli, N. (2015). Assessing the operating reserves and costs with considering customer choice and wind power uncertainty in pool-based power market. *International Journal of Electrical Power & Energy Systems*, *67*, 202–215. http://doi.org/10.1016/j.ijepes.2014.11.007

Short, J. A., Infield, D. G., & Freris, L. L. (2007). Stabilization of Grid Frequency Through Dynamic Demand Control. *IEEE Transactions on Power Systems*, *22*(3), 1284–1293. http://doi.org/10.1109/TPWRS.2007.901489

Sigrist, L., Egido, I., & Rouco, L. (2012). A method for the design of UFLS schemes of small isolated power systems. *IEEE Transactions on Power Systems*, *27*(2), 951–958. http://doi.org/10.1109/TPWRS.2011.2174448

Singh, P., Titare, L. S., & Arya, L. D. (2011). Under Voltage Load Shedding using Evolution Strategy to Enhance Voltage Stability, (i), 2–6.

Solé, R. V., Rosas-Casals, M., Corominas-Murtra, B., & Valverde, S. (2008). Robustness of the European power grids under intentional attack. *Physical Review E*, *77*(2), 026102. http://doi.org/10.1103/PhysRevE.77.026102

Son, S.-Y., & Chung, B.-J. (2009). A Korean Smart Grid architecture design for a field test based on power IT. In *2009 Transmission & Distribution*

Conference & Exposition: Asia and Pacific (pp. 1–4). IEEE. http://doi.org/10.1109/TD-ASIA.2009.5356842

Son, Y., Pulkkinen, T., Moon, K., & Kim, C. (2010). Home energy management system based on power line communication. *IEEE Transactions on Consumer Electronics*, *56*(3), 1380–1386. http://doi.org/10.1109/TCE.2010.5606273

Su, H. J., Chang, G. W., Ranade, S., & Lu, H. J. (2012). Modeling and simulation of an ac microgrid for harmonics study. In *2012 IEEE 15th International Conference on Harmonics and Quality of Power* (pp. 668–672). IEEE. http://doi.org/10.1109/ICHQP.2012.6381209

Tang, J., Liu, J., Ponci, F., & Monti, A. (2013). Adaptive load shedding based on combined frequency and voltage stability assessment using synchrophasor measurements. *Power Systems, IEEE Transactions on*, *28*(2), 2035–2047. http://doi.org/10.1109/TPWRS.2013.2241794

Taqqali, W. M., & Abdulaziz, N. (2010). Smart Grid and demand response technology. In *2010 IEEE International Energy Conference* (pp. 710–715). IEEE. http://doi.org/10.1109/ENERGYCON.2010.5771773

Tenaga Nasional Berhad. (2001). *Electricy Supply Application handbook* (2nd ed.).

Trefke, J., Rohjans, S., Uslar, M., Lehnhoff, S., Nordstrom, L., & Saleem, A. (2013). Smart Grid Architecture Model use case management in a large European Smart Grid project. In *IEEE PES ISGT Europe 2013* (pp. 1–5). IEEE. http://doi.org/10.1109/ISGTEurope.2013.6695266

Tsado, Y., Lund, D., & Gamage, K. (2014). Resilient wireless communication networking for Smart grid BAN (pp. 846–851). http://doi.org/10.1109/ENERGYCON.2014.6850524

Ullah, I., Javaid, N., Imran, M., Khan, Z. A., Qasim, U., Alnuem, M., & Bashir, M. (2015). A Survey of Home Energy Management for Residential Customers. In *2015 IEEE 29th International Conference on Advanced Information Networking and Applications* (Vol. 5, pp. 666–673). Gwangiu: IEEE. http://doi.org/10.1109/AINA.2015.251

Usman, M. (2013). Use of Telecom Energy for Smart Grid, (September). Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A678757&dswid=-6364

Varaiya, P. P., Wu, F. F., & Bialek, J. W. (2011). Smart Operation of Smart Grid: Risk-Limiting Dispatch. *Proceedings of the IEEE*, *99*(1), 40–57. http://doi.org/10.1109/JPROC.2010.2080250

Vivekananthan, C., Mishra, Y., Ledwich, G., & Li, F. (2014). Demand Response for Residential Appliances via Customer Reward Scheme. *IEEE Transactions on Smart Grid*, *5*(2), 809–820. http://doi.org/10.1109/TSG.2014.2298514

von Dollen, D. (2009). *Report to {NIST} on the Smart Grid Interoperability Standards Roadmap*. *Electric Power Research Institute (EPRI) and National Institute of Standards and Technology*. Retrieved from ftp://24.22.29.138/UNTITLED/netbook files/MKTG 548/smart grid files/report to nist on the smart grid interoperability.pdf

Wang, Y. W. Y., Wang, B. W. B., & Liang, M. L. M. (2010). A smart power system cascading failure accident prediction model based on probability analysis. *Power System Technology (POWERCON), 2010 International Conference on*. http://doi.org/10.1109/POWERCON.2010.5666720

Weckx, S., D'Hulst, R., & Driesen, J. (2015). Primary and Secondary Frequency Support by a Multi-Agent Demand Control System. *IEEE Transactions on Power Systems*, *30*(3), 1394–1404. http://doi.org/10.1109/TPWRS.2014.2340582

Ye Li, Baohui Zhang, Zhiqian Bo, Li, Y., Zhang, B., Member, S., & Bo, Z. (2014). The optimization of undervoltage load shedding strategy. In *2014 International Conference on Power System Technology* (pp. 164–169). IEEE. http://doi.org/10.1109/POWERCON.2014.6993553

Zanden, G. Van Der. (2011). The Smart Grid in Europe :, (September).

Zhao, Z., Lee, W. C., Shin, Y., Member, S., Song, K.-B., Zhuang Zhao, … Kyung-Bin Song. (2013). An Optimal Power Scheduling Method for Demand Response in Home Energy Management System. *IEEE Transactions on Smart Grid*, *4*(3), 1391–1400. http://doi.org/10.1109/TSG.2013.2251018

Zin, A. M. A. A. M., Hafiz, H. M. M., & Aziz, M. S. S. (2004). A review of under-frequency load shedding scheme on TNB system. In *PECon 2004. Proceedings. National Power and Energy Conference, 2004.* (pp. 170–174). IEEE. http://doi.org/10.1109/PECON.2004.1461637