IoT Based Energy Monitoring and Outage Reporting

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Abstract—Leading to a significant rise demand in electrical energy from the quickly rising population of the world, will cause a dearth of electrical energy in the future world. Many smart devices will be incorporated into residentials in smart cities that participate in the electricity bazaar through the response of demand programs with the creation of the IoT to effectively respond to demand (DR) programs. Manage energy to meet this growing demand for energy. With this opportunity, an energy management plan for IoT-enabled residential buildings is therefore built using a price-based DR program. We propose an algorithm for WBFA (wind-driven bacterial foraging), which is a combination of algorithms for WDO (Wind driven optimization) and BFO (Bacterial Foraging Optimization). With algorithms, Continuously, we built a plan based on our proposed WBFA to control the power consumption of smart IoT-enabled residentials appliance by planning to reduce the PAR (Peak-to -Average Ratio), reduce energy costs and optimize user comfort (UC). This increases the productive use of electricity, which in turn increases IoT-enabled residential sustainability. In order to combat the important problems of DR programs, the WBFA-based strategy responds to price-based DR programs, which is the weakness of the knowledge of customers to respond while receiving DR signals. Substantial simulations are being carried out to help the productivity and efficiency of the proposed idea of the WBFA-based strategy. In addition, the proposed WBFA-based approach is compared with benchmark strategies, including the algorithm for BPSO (Binary Particle Swarm Optimization), GA (Genetic Algorithm), the algorithm for GWDO (Genetic Wind-Driven Optimization) and the algorithm for genetic binary particle swarm optimization (GBPSO) in terms of consumption of energy, electricity cost, UC and PAR.

Keywords—IoT; Energy Monitoring; Power Demand Management; Wireless; Peak-to-Average Ratio

I. Introduction

As population growth is rapid and economic development, reliance on electricity is on the rise and energy usage is on the rise. In addition, the authors pointed out that the demand for electricity in the energy sector will rise to 40 percent and both the industrial and the sectors of residence will rise to 25% by 2026. This growing demand for electricity and contemporary problems such as two-way communication, hybrid generation and two-way power flow are not able to cope with the obsolete electric grid. The new power grid, namely the SG (Smart Grid), has therefore been built as a smart grid that accommodates the IoT (Internet of Things), modern control technologies,. ICTs (Information and Communication Technologies), power flow in two directions, and hybrid generation. In order to cope with this rising demand for electricity, SG can actively involve either of the two programs: power generation plant construction or energy management broadcast DR (Demand Response) programs.

DR programs are main SG programs incentive that attracts customers through advanced metering technology to participate in the electrical market (AMI). The DR program has two classes: (a) DR programs based on incentives and (b) DR programs based on costs. In a DSOs (Distribution System Operators) are IoT -enabled agents that, with short notice in advance, remotely control consumer appliances when necessary. In (b), in reaction to provided price-based incentives, IoT enabled users can be encouraged to spontaneously control their power usage[3]. Since buildings have an energy consumed over 80 percent, a large portion of the total energy consumption.

One challenge of DR systems is the user awareness that helps users from participating. The solutions developed is to automatic controllers in user program, known as energy management controllers, actively takes place and contributed in solving an optimization problem (EMC). When activated with IoT, the EMC can effectively minimize the cost of electricity for consumers. The EMC performance of residential building smart appliances is the optimum power use plan. In addition, in order to boost sustainability, plugin hybrid electric vehicles (PHEVs), smart appliances RESs (Renewable Energy Sources) and energy storage systems will penetrate residential buildings[7,8]. Home PHEVs and energy storage systems therefore promote the storage of energy from RESs by consumers. Goals, however, are accomplished at a high cost of resources. In references [9,10,11], the authors suggested energy use scheduling techniques for energy management of residential buildings. In minimizing energy costs as well as peak electricity demand, the strategies developed are helpful. In addition, users are drawn to active involvement in these works due to cost. Minimization without UC being sacrificed. Via power use scheduling using DR programs, the authors implemented a novel concept of consumer priority in management of energy systems. Household appliances with priority as well as operational and thermal constraints allow EMC, on a priority basis, to switch on and off appliances.

Sufficient researches related to the topic of energy management in SG are given in the literature above. Although the emphasis of studies is on cost minimizing, few studies catered to the reduced of peak demand, some studies catered to the peak to average ratio of alleviation (PAR), and few studies dealt with UC. To the betterment of our understanding, no studies completely exploited AMI, DR services, SG's IoT-enabled environments to accommodate all parties' users and DSOs at the same time. Therefore, in this report, we use SG's AMI, DR systems, and IoT-enabled environments to perform efficient energy management of smart city residential buildings in order to minimize cost, reduce PAR,and optimize UC,subsequently for the satisfaction of both users and DSOs.

II. Energy Management Based on Mathematical Models

A. *Linear Programming Model*

The LP (Linear Programming) to schedule the charge/discharge of batteries and the operation of smart home/industrial appliances using RTPS and DAPS DR program to promote the reduction of energy costs and the maximization of UC for consumers. An energy management system mechanism based on an integer LP (ILP) is generated. Built in Comparison [21] for cost reduction and peak load mitigation. The model of building is a hybrid power grid and PV architecture provides loads of residence. But, at the cost of increased complexity and elevated execution time, the desired goals are achieved. For efficient energy, a mixed integer non-LP MINLP-based residence of the load scheduling the mechanism is being developed. With appropriate UC, residential building appliance which are critical, deferrable, and thermal non-deferrable are designed to reduce electricity costs. In Comparison [24], novel fractional programming tools are built for house appliance energy management. The goal is to reduce costs for distributed energy resources (DERs) and electricity utility companies by household load scheduling. In Comparison [24], novel fraction programming tools are built for home energy management. The goal is to reduce costs for distributed energy resources (DERs) and electricity utility companies by household load scheduling. The authors developed a prototype based on MINLP for the scheduling of HVAC (Heating, Ventilating and Air-Conditioning) systems using the cost and HVAC constraints in Reference[25]. For residential building energy management, a predictive mixed integer programming (PMIP)-based scheduling mechanism[26] has been developed. The authors strive to minimize energy costs and to mitigate demand peaks. A novel based on SMPC (Stochastic Model Predictive Control) and MINLP for house appliances and energy resources scheduled was proposed by the authors in Reference[27]. A collaboration economic model for power use schedule of smart cities based on a model predictive control (MPC) algorithm is built in Comparison [28]. The integrated strategy aims to manage the increase in demands for electricity with resources available and to minimize costs. For urban areas with diverse energy sources, an intelligent MILP-based model is being developed[29].

B. *Energy Management Based Meta-Heuristic and Heuristic Methods*

In Comparison, suggested a scheduled strategy focused in heuristic based algorithms such as a glow-worm swarm particle optimized algorithm is successful for the management of energy. In terms of performance metrics, the developed model is endorsed through evaluation of comparative benchmark schemes. The new mechanism consists of machine learning models and household load scheduling heuristic algorithms such as deferrable load, fixed load, and regulate-able load using DR program. For DSM (Demand Side Management) of the commercial, industrial and residential sectors establishes a system based on an evolutionary algorithm (EA). In order to cope with increasing energy demand, the authors plan to minimize costs and peaks in electricity usage. However, relative to both the manufacturing and commercial industries, the cost of minimization of energy in the residential sector is lower. A stratergically based on the BFO(Bacterial Foraging Optimization) algorithm was developed by the authors to minimize energy costs and user discomfort.

The authors used EMC based on GA for scheduling house appliances The EMC based GA uses the combined RTPS and IBRS(Inclined Block Rate System) to schedule household appliances in order to reduce electricity prices, alleviate peak load demand, and solve the problem of energy scarcity.

In order to meet increasing electricity demand, the EMC based on the PSO (Particle Swarm Optimization) and its variant are used in Comparison to schedule residential building ,energy resources , battery charging/discharging scheduling and, smart appliances. This study aims to simultaneously mitigate peak load demand and energy costs. A new WDO algorithm is built in References[25,26] for solving household appliances scheduling. Based on the algorithm WDO and its variants, the EMCs used are intended to minimizing electricity and UC costs in waiting time. Algorithms such as Meta-heuristic are used in References [23,24] to program EMC for residence building power usage scheduled.

III. Proposed Energy Management Framework

This section elaborates on the proposed framework. The DSOs is an IoT enabled agency that transfers DR programs such as RTPS, DAPS, and ToUPS to encourage IoT enabled in users to active participation in energy management using received DR signals through power used in scheduled in residentials smart appliances. The proposed structure is made up of IoT enabled in the DSOs and residences that use AMI of SG. The IoT-enabled residents are equipped with EMC, remote control, indoor display (IDD), home gateway, smart devices, smart meter, and network wireless home area.

The AMI is essential attribute to the IoT enabled SG that plays a vital role in the energy management of the central nervous system via power use scheduling. AMI's key role is to obtain and deliver energy consumption which is recorded to DSOs from meters and to transmit DR signals pricing from DSOs to consumers in real-time through residential building gateways and smart meters. The buildings gateway could be an individual device or could has an integral smart meter that creates a HAN and wired network interface.

The smart meter's main duty is to calculate, register, and process energy consumed and transmitted by the DSOs. In addition, to conduct efficient energy management, it transmits DR pricing signals to the IoT embeded EMC. The residential buildings under this research is equipped with intelligent equipment such as power ,adjustable appliances, time-adjustable , and critical appliances appliances. The adjustable power devices has elastic rated power and pre-defined schedule of operation. The time flexible devices have an elastic running time and equipped for fixed-power operation. They are further graded as interruptible (washing machine ,washing machine, and tumble dryer) and non-interruptible (heater vacuum cleaner and electric water) in two classes[18]. The IoT enabled EMC employed in the residentials, with the program which is proposed by the WBFA to respond in real-time to receive DR pricing signals to combat the limitation of the dearth of users' knowledge .To schedule power use of buildings smart appliances in the presence of constraints and objective purpose, the employed EMC based WBFA activated with IoT makes smart appliances power ranking, price based DR programs, accessible power grid energy and length of time operation as inputs. In a residential building, the IoT-enabled EMC can connect with smart devices through various communication links such as Wi-Fi, Z-Wave , HomePlug, and ZigBee to share the generated power consumption scheduled with smart equipments. The residentials energy management process is controlled by IDD or remotely via laptops via power consumption scheduling of smart appliances.

IV. IoT Based Energy Monitoring and Outage ReportingThe

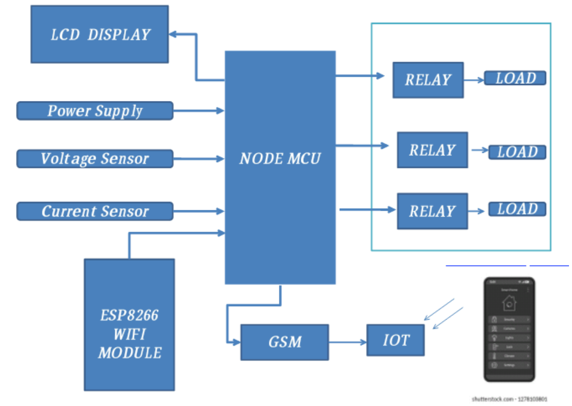


Fig. 1. Block Diagram IoT Based Energy Monitoring and Outage Reporting

The proposed energy management mechanism is discussed in above block diagram. Energy management is defined in Section 4 by scheduled problem definition and formulation. Section 5, proposed and benchmark strategies are identified. Extensive simulations are carried out and their findings are discussed.

In SG, the literature has been carried in the field of energy management to cope with the increasing demand for electricity. The subject-relevant literature is categorized into types: (a) mathematical model-based energy management, (b) meta-heuristic and heuristic method-based energy management, and (c) hybrid method-based energy management. For measuring and monitoring the real-time electrical power parameters is required the following sensors.

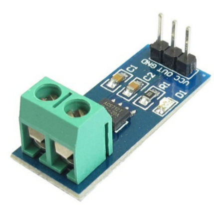
A. NODE MCU's

The Node MCU is the open source firmware for which board designs are available for open source prototyping. The "Node MCU" name blends "node" with "MCU" (micro-controller unit). Strictly speaking, the word 'Node MCU' refers to the firmware rather than the development kits associated with it.

Fig. 2. Node MCU's

B. Voltage Sensor, Current Sensor and Relay

Voltage sensor is a sensor that is used to measure and monitor the voltage level of an entity. The AC



voltage or DC voltage level can be calculated by voltage sensors. This sensor's input is the voltage, whereas switches, analog voltage signal, current signal, or audible signal are the output.

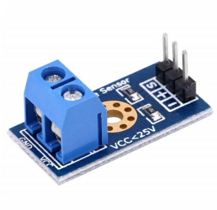


Fig. 3 Voltage Sensor, Current Sensor

ACS712 Current Sensor Module - 20A is based on an ACS712 sensor that senses AC or DC current accurately. The maximum AC or DC that can be sensed can exceed 20A and the current signal can be read through a microcontroller or Arduino analog I/O port.

V. Results and Discussion

Once the entire proposed project has been deployed into field, the monitoring process could automatically boot up. The results has been took from the various sensors and the measured data's are sent to Thing Speak server for further analysis. The various measured data are made as graph as follow as,

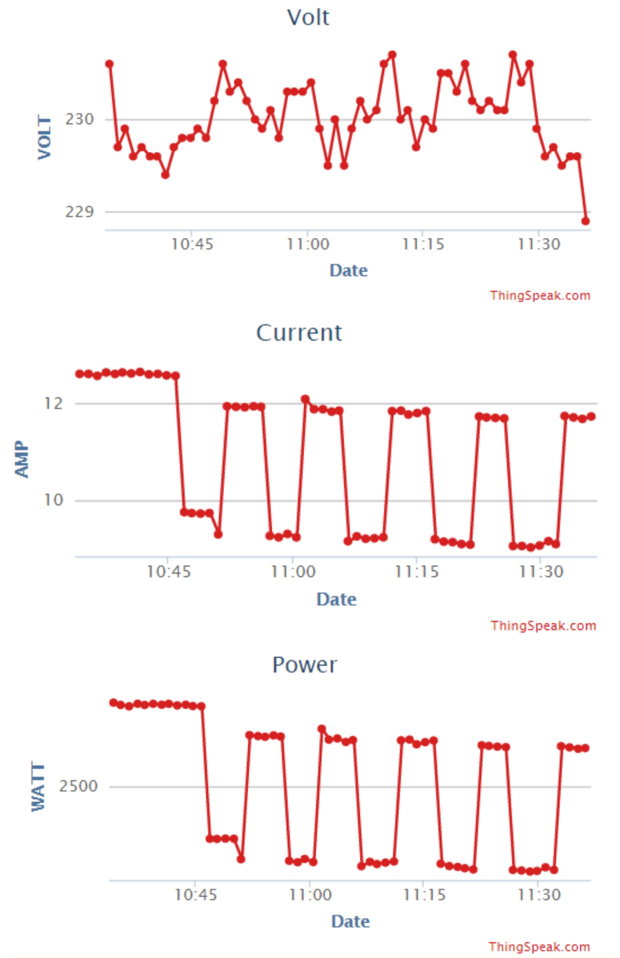


Fig. 4. Voltage, Current and Power in the line

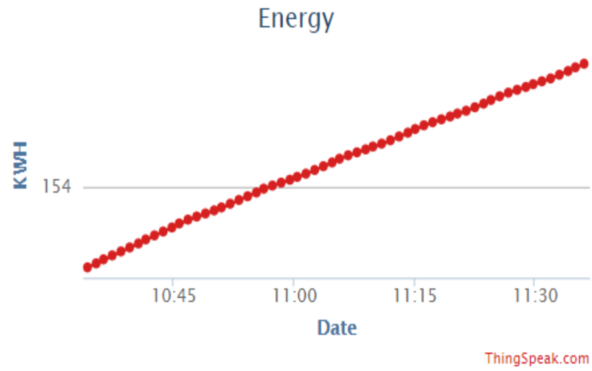


Fig. 5. Measured Power

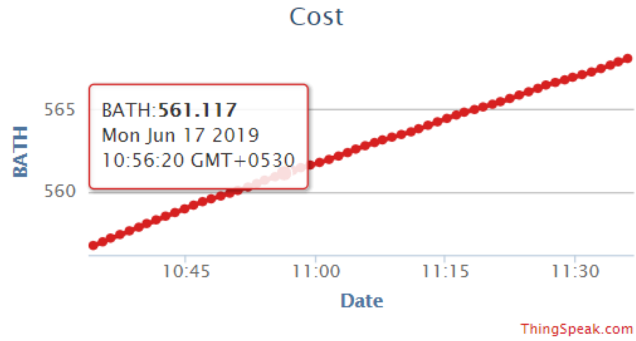


Fig.6 Cost Calculation

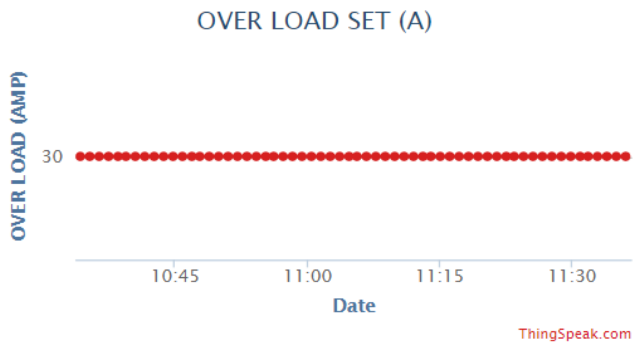


Fig. 7. Demand Load set

VI. Conclusion

By employing DR systems, power efficient, optimum usage of electricity, and cost of minimization can be achieved. The lack of expertise, however, precludes the creation and employment of DR programs in customer premises. Various approaches are used to implement and use DR systems for energy conservation, such as classical, statistical, heuristic, meta-heuristic, and hybrid. We recommend the WBFA algorithm in this work, is a combination of the algorithms of BFO and WDO. The programmed EMC in our proposed algorithm responds automatically to DR programs to take part in residential building management of energy in the SG's IoT-enabled environment. The results of the simulation show that the use of ToUPS DR for management of energy contributes to the low cost of power, PAR, and reliable energy use scheduled for smart residentials buildings appliances compared to RTPS DR systems and DAPS. Therefore, the use of the DR software for energy management contributes to beneficial energy management.

VII. REFERENCES

[1] Park, Sung Wook, Lee B. Baker, and Paul D. Franzon. "Appliance identification algorithm for a non-intrusive home energy monitor using cogent confabulation." IEEE Transactions on Smart Grid 10, no. 1 pp. 714-721, 2017

[2] Barman, Bibek Kanti, Shiv Nath Yadav, Shivam Kumar, and Sadhan Gope. "IOT based smart energy meter for efficient energy utilization in smart grid." In 2018 2nd International Conference on Power, Energy and Environment: Towards Smart Technology (ICEPE), pp. 1-5. IEEE, 2018.

[3] Arif, Anmar, Muhannad Al-Hussain, Nawaf Al-Mutairi, Essam Al-Ammar, Yasin Khan, and Nazar Malik. "Experimental study and design of smart energy meter for the smart grid." In 2013 International Renewable and Sustainable Energy Conference (IRSEC), pp. 515-520. IEEE, 2013.

[4] Sun, Qie, Hailong Li, Zhanyu Ma, Chao Wang, Javier Campillo, Qi Zhang, Fredrik Wallin, and Jun Guo. "A comprehensive review of smart energy meters in intelligent energy networks." IEEE Internet of Things Journal 3, no. 4, pp. 464-479, 2015.

[5] Preethi, V., and G. Harish. "Design and implementation of smart energy meter." In 2016 International Conference on Inventive Computation Technologies (ICICT), vol. 1, pp. 1-5. IEEE, 2016.

[6] Sahani, Birendrakumar, Tejashree Ravi, Akibjaved Tamboli, and Ranjeet Pisal. "IoT based smart energy meter." International Research Journal of Engineering and Technology (IRJET) 4, no. 04 pp. 96-102, 2017.

[7] Muralidhara, Shishir, Niharika Hegde, and P. M. Rekha. "An internet of things-based smart energy meter for monitoring device -level consumption of energy." Computers & Electrical Engineering pp.106772, 2020.

[8] Lee, Chao-Hsien, and Ying Hsun Lai. "Design and implementation of a universal smart energy management gateway based on the Internet of Things platform." In 2016 IEEE International Conference on Consumer Electronics (ICCE), pp. 67-68. IEEE, 2016.

[9] Rashid, Rozeha A., Leon Chin, Mohd Adib Sarijari, Rubita Sudirman, and Teruji Ide. "Machine learning for smart energy monitoring of home appliances using IoT." In 2019 Eleventh International Conference on Ubiquitous and Future Networks (ICUFN), pp. 66-71. IEEE, 2019.

[10] Hiwale, Abhiraj Prashant, Deepak Sudam Gaikwad, Akshay Ashok Dongare, and Prathmesh Chandrakant Mhatre. "Iot Based Smart Energy Monitoring." International Research Journal of Engineering and Technology Vo. 5, no. 03, 2018.

[11] Sayed, Khairy, and Hossam A. Gabbar. "SCADA and smart energy grid control automation." In Smart Energy Grid Engineering, pp. 481-514. Academic Press, 2017.

[12] Saikia, L. C., Himshekhar Das, NB Dev Choudhury, and T. Malakar. "GPRS enabled smart energy meter with in-home display and application of time of use pricing." In 2016 IEEE Annual India Conference (INDICON), pp. 1-5. IEEE, 2016.

[13] Alan, Alper T., Enrico Costanza, Sarvapali D. Ramchurn, Joel Fischer, Tom Rodden, and Nicholas R. Jennings. "Tariff agent: interacting with a future smart energy system at home." ACM Transactions on Computer-Human Interaction (TOCHI) 23, no. 4 pp. 1-28, 2016

[14] Pawar, Prakash, and Mudige TarunKumar. "An IoT based Intelligent Smart Energy Management System with accurate forecasting and load strategy for renewable generation." Measurement 152 pp. 107187, 2020.

[15] Han, Jinsoo, Chang-Sic Choi, Wan-Ki Park, Ilwoo Lee, and Sang-Ha Kim. "Smart home energy management system including renewable energy based on ZigBee and PLC." IEEE Transactions on Consumer Electronics 60, no. 2 pp. 198-202, 2014.

[16] Chaudhari, Sneha, Purvang Rathod, Ashfaque Shaikh, Darshan Vora, and Jignesha Ahir. "Smart energy meter using Arduino and GSM." In 2017 International Conference on Trends in Electronics and Informatics (ICEI), pp. 598-601. IEEE, 2017.

[17] Jayanthi, R., and S. T. Rama. "IOT Based Smart Energy Tracking System." International Journal of MC Square Scientific Research (IJMSR) 9, no. 1, pp. 98-108, 2017.

[18] Farmani, Farid, Mehdi Parvizimosaed, Hassan Monsef, and Ashkan Rahimi-Kian. "A conceptual model of a smart energy management system for a residential building equipped with CCHP system." International Journal of Electrical Power & Energy Systems 95 pp. 523-536, 2018.

[19] Mani, Vignesh, Abhilasha Gunasekhar, and S. Sankaranarayanan. "Iot based smart energy management system." International Journal of Applied Engineering Research 12, no. 16 pp. 5455-5462, 2017.

[20] Song, Xujiang, Ruihong Ma, Zhengxiang Ma, Min Zhang, Amin Gholamzadeh, Nadim Hossain, and Shuping Dang. "Multifunctional smart electricity use monitor design, programming and tests based on LabVIEW." In 2014 International Conference on Information Technology Systems and Innovation (ICITSI), pp. 299-305. IEEE, 2014.

[21] Cheng, Lefeng, and Tao Yu. "A new generation of AI: A review and perspective on machine learning technologies applied to smart energy and electric power systems." International Journal of Energy Research 43, no. 6 pp. 1928-1973, 2019.

[22] Chapaloglou, Spyridon, Athanasios Nesiadis, Petros Iliadis, Konstantinos Atsonios, Nikos Nikolopoulos, Panagiotis Grammelis, Christos Yiakopoulos, Ioannis Antoniadis, and Emmanuel Kakaras. "Smart energy management algorithm for load smoothing and peak shaving based on load forecasting of an island's power system." Applied Energy 238 pp.: 627-642, 2019.

[23] Labib, Labib, Masum Billah, GM Sultan Mahmud Rana, Md Nazmus Sadat, Md Golam Kibria, and Md Rafiqul Islam. "Design and implementation of low-cost universal smart energy meter with demand side load management." IET Generation, Transmission & Distribution 11, no. 16 pp. 3938-3945,2017.

[24] Iqbal, HM Zahid, M. Waseem, and Tahir Mahmood. "Automatic energy meter reading using smart energy meter." In Proc. Int. Conf. Engineering & Emerging Technologies, pp. 1-5. 2014.

[25] Strengers, Yolande, Sarah Pink, and Larissa Nicholls. "Smart energy futures and social practice imaginaries: Forecasting scenarios for pet care in Australian homes." Energy research & social science 48 pp. 108-115, 2019.

[26] Tsou, Yu-Ping, Jun-Wei Hsieh, Cheng-Ting Lin, and Chun-Yu Chen. "Building a remote supervisory control network system for smart home applications." In 2006 IEEE International Conference on Systems, Man and Cybernetics, vol. 3, pp. 1826-1830. IEEE, 2006.