OpenADR: Automated Demand Response Literature Review

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***Abstract*— This document provides background information on OpenADR, the standard for Automated Demand Response (ADR) and how it is beneficial for the operation of power grid systems.**

I. Introduction

The purpose of Automated Demand Response (ADR) is to manage and reduce demand for power grid systems during strenuous times such as a hot summer day or cold winter night. In cases where a region uses more energy than a utility company can produce, blackouts and brownouts may occur. With the use of ADR, these outcomes can be proactively avoided.

II. Background

Demand Response (DR) within the power grid is the process of managing demand during peak energy usage periods. This concept may be done manually by messaging energy users to turn off high usage devices during peak times. ADR brings automation into the picture by working alongside other technologies such as Internet of Things (IoT). Utility companies will typically offer financial incentives to customers in the Automated Demand Response program. Increased prices during peak energy usage is not an uncommon concept. Through ADR customers can automatically minimize their price increases through optimized energy usage.Rather than manually requesting for customers to adjust electricity usage, by being interconnected to devices ADR may automatically turn them off. An example is utility companies cycling air conditioning and water heating on and off in residential areas via direct control, to lower the demand in peak hours. With the introduction of smart grid systems and advancement in communication technology, ADR capabilities have increased drastically, allowing for critical infrastructure to be more reliable.

Due to the nature of how important critical infrastructure is, OpenADR has been established to "standardize, automate, and simplify Demand Response" (OpenADR). There are two key components to OpenADR 2.0, the most popular version. The first Key component is virtual top nodes (VTN), which represent utilities or grid operators that send demand response signals. The second key component is virtual end nodes (VEN), which represent devices/systems that actually respond to those signals, like smart thermostat devices or industrial control systems. How the step by step system works is that the VTN (grid operator) will send a demand response signal to participating customers using the OpenADR protocol. The VEN (consumer) device will receive the response signal and automatically adjust power consumption. Some examples of this would be a commercial building dimming its lighting, or air conditioning slightly raising the temperature or cycling off for a period of time.

III. Impact of OpenADR

OpenADR Was initially developed by the Lawrence Berkeley National Laboratory, and has been widely adopted as the global standard to implement ADR systems. OpenADR allows for customers (utility companies) to use automated and secure Demand Response programs, as well as allows for scalable demand response communication. This benefits utility companies by allowing them to reduce demand in times of need without any manual input. The main impacts of OpenADR is the grid reliability, economic benefits of reducing energy consumption, and the ability to integrate renewable energy systems. By automating demand response, systems are able to quickly reduce peak loads and prevent grid failures.

OpenADR is one of 16 Grind Standards and is given this standard by the U.S. Department of Energy the National Institute of Standards and Technology Smart Grid Interoperability Standards effort. The framework is viewed as an international standard for Demand Response systems and presently used around the world.

Additionally, OpenADR supports Virtual Power Plants (VPPs) by coordinating distributed energy resources (DERs) such as battery storage or electric vehicles to utilize energy. This allows for new infrastructure

development, for example a police station that utilizes renewable energy like solar panels to produce their own energy and store excess energy that can be distributed via the OpenADR system (medford energy). Some of the challenges facing OpenADR are the cybersecurity concerns, as it is a cloud based system.

IV. OpenADR Standards/Protocols

OpenADR is based on a standardized set of protocols designed to allow automatic and secure communication between energy customers and utilities. These protocols help utilities manage demand response scenarios by guaranteeing compatibility across different devices and systems.

The most widely used version of OpenADR is OpenADR 2.0, which was developed by the OpenADR Alliance. It provides an organized method of responding to requests and is designed to be flexible enough to be used for a variety of purposes. There are two main profiles for OpenADR 2.0.

OpenADR 2.0a: This profile is a condensed version suited for smaller-scale uses, like demand response in homes. Simple demand response automation is made possible by its support for simple, one-way communication between utilities and consumer devices.

OpenADR 2.0b: is utilized in business and industrial settings. Virtual Top Nodes (VTNs) and Virtual End Nodes (VENs) can communicate in real time thanks to its two-way communication capabilities. This makes it possible to control load in a more responsive and dynamic manner.

V. OpenADR Case Studies

Several case studies show that OpenADR is being implemented in several industries such as Sunpower for California utilities and virtual power plants and Bellawatt for utilities in New Hampshire. Additionally, Ford has joined the Board of Directors for OpenADR, solidifying the importance of OpenADR for electric utilities moving forward.

VI. Use of AI and Machine Learning with ADR

AI programs such as OpenLEADR exist in compliance with openADR that will automatically register nodes, Automatically report clients, and automatically sign outgoing signals cryptically. This program is still in the project stage, as the automated of DER communication is relatively new, there is still much to be explored.

VII. OpenADR Security Vulnerabilities

By nature of the OpenADR software a large amount of trust must be granted by customers, the ability to control the power of devices in their home. A singular house has a miniscule impact on the overall powergrid. For OpenADR to be effective in application it requires a significant amount of consumers to participate in the system. This means that consumer comfort and security plays a large part in the overall effectiveness of the technology.

Open source software has its advantages as well as disadvantages with building trust with customers.

VIII. Technical Implementations

DER board

IX. Conclusion

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[11] Augello, A., P. Gallo, E. R. Sanseverino, G. Sciumè, and M. Tornatore. "A Coexistence Analysis of Blockchain, SCADA Systems, and OpenADR for Energy Services Provision." *IEEE Access*, vol. 10, 2022, pp. 99088-99101. IEEE, https://doi.org/10.1109/ACCESS.2022.3205121.

Annotated Bibliography / Article Summaries

Augello, A., P. Gallo, E. R. Sanseverino, G. Sciumè, and M. Tornatore. "A Coexistence Analysis of Blockchain, SCADA Systems, and OpenADR for Energy Services Provision." *IEEE Access*, vol. 10, 2022, pp. 99088-99101. IEEE, https://doi.org/10.1109/ACCESS.2022.3205121.

Interconnecting systems on the powergrid, due to the sheer scale, requires a combination of technologies. This paper discusses multiple technologies involving the optimization of our energy system. Some technologies discussed are Blockchain, Supervisory Control and Data Acquisition (SCADA) Systems, Internet of Things (IoT), and OpenADR. SCADA currently dominates this area of technology within the power grid but many modern ideas propose a shift to IoT where energy devices may become easier for systems to manage. A detailed description of how OpenADR works, its protocols, how it interacts with IoT and more are discussed in this paper. There are also examples given of systems such as an Italian Model for DR, SCADA systems, Blockchain, and Unified Architecture models. Overall this paper is quite in depth, but the discussion of the wide variety of technologies present in this field prove to be useful. Having a comprehensive understanding of not only OpenADR but the technologies it will work alongside is crucial in maximizing the performance of OpenADR. The paper was published in 2022 making it quite recent and relevant in the discussion of the current state of the OpenADR framework.

"Automated Demand Response." *Medford's Go Green Initiative!*, City of Medford, https://medfordenergy.org/gogreen/automated-demand-response/. Accessed 4 Feb. 2025.

The power grid is a fluid system that goes through peaks and valleys. Peak times such as hot summer days or cold winter nights result in high energy consumption. Large energy consumption days result in not only higher electricity bills but can potentially cause blackouts. Automated Demand Response (ADR) works to increase the power grids efficiency and capacity by optimizing energy using devices during these peak energy usage days. Through signaling connected systems to turn on or off the energy load is able to be decreased, not only at peak times but at all times. Medford, MA has several energy efficient buildings with energy sources such as solar panels. These buildings not only are able to function off of the grid due to their energy generation but are also beginning to implement ADR systems. The usage of ADR systems can better support off grid systems and create more confidence in the ability to independently power buildings.

Electric Power Research Institute (EPRI). *OpenADR-Virtual-Top-Node.* GitHub, February 4, 2025. https://github.com/epri-dev/OpenADR-Virtual-Top-Node.

Implementation example of a virtual top node (TVP) as used in OpenADR.

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Implementation example of setting up IoT Security demo on PCB or Breadboard hardware.

"OpenADR & Communications | Building Technology and Urban Systems." *Lawrence Berkeley National Laboratory*, 2019, https://buildings.lbl.gov/openadr-communications. Accessed 4 Feb. 2025.

During the 2002 California electricity crisis OpenADR was developed at Berkeley Lab. OpenADR is one of 16 Smart Grid Standards supported by the U.S. Department of Energy the National Institute of Standards and Technology Smart Grid Interoperability Standards effort. Specific examples of messages OpenADR uses to communicate between the VTN and VEN are included. These messages show how the system might communicate for identifying the current electrical loads. The OpenADR framework is accepted as an international standard and is presently used across the United States as well as around the world.

Park, M., Kang, M., and Choi, J.Y. "The Research on Vulnerability Analysis in OpenADR for Smart Grid." Data Analytics for Renewable Energy Integration, edited by Woon W., Z. Aung, and S. Madnick, vol. 8817, Springer, 2014, https://doi.org/10.1007/978-3-319-13290-7_4.

As society's dependence on electric power continues to grow, technology continues to look into accommodating the demand. Demand Reduction (DR) is used to manage and reduce the demand for electricity. OpenADR is an open source protocol of DR that is meant to be used within the context of a Smart Grid. This article discusses security weaknesses within OpenADR which largely surround improper coding practices. CERT Java is a set of secure coding rules that identify violations relating to static, complexity, and data flow. Rule OBJ01-J, for example, requires data members be declared as private and made accessible with wrapper methods. At the time of this article, OpenADR was found to violate this rule more than 720 times. Insecurities of this nature may lead to detrimental consequences with real world applications. This article was published in 2014 and OpenADR has likely fixed many of these insecurities. However, the importance of ensuring quality and security from open source software can still be highlighted. The LDRA Testbed and the set of CERT Java policies are excellent examples of tools that can be used to ensure secure and high quality code.

Yassine, A. "Implementation Challenges of Automatic Demand Response for Households in Smart Grids." *Proceedings of the 3rd International Conference on Renewable Energies for Developing Countries (REDEC)*, 2016, pp. 1-6. IEEE, https://doi.org/10.1109/REDEC.2016.7577546.

Demand Response (DR) systems have largely been used in industrial contexts where electrical draw can be extremely large. As Smart Grid systems advance and the number of residential consumers increases on the power grid DR systems become more common in residential settings. OpenADR utilizes VEN gateways that communicate between the consumer and Demand Response Service Providers (VTN) which supplies energy to consumers. With OpenADR, DR systems are able to be automated and remove the need to manually contact users about energy consumption. This article discusses the benefits of OpenADR such as customer control, supporting household contribution to energy conservation, the integration of renewable energy sources, and more. Challenges with implementing OpenADR on a large scale are also discussed, the main four being: privacy, security, scalability, and user acceptance. While an individual household does not have much impact on the power grid the conglomeration of all households does. OpenADR has the potential to have a large impact on energy consumption from residential households making the challenges worth overcoming.