Journal of Artificial Intelligence and Computing (JAIC)
ISSN (p): 3005-3358
Volume: 1, Number: 2, Pages: 6- 12, Year: 2023

Computing the Demand Response in a Renewable Dominated Power System

Muhammad Moiz, Muhammad Moeez, Saad Shakeel and Waseem Akram

Electrical Engineering Department, Government College University, Lahore, 54000, Pakistan
Corresponding author: Muhammad Moeez (Email: moeezanser27@gmail.com)

Received: 12/06/2023, Revised: 22/10/2023, Accepted: 15/11/2023

Abstract-- **Demand response refers to action where consumers can significantly optimize the electricity grid by reducing or shifting power consumption during peak periods using time-based rates or economic incentives. In this project, we have proposed a system where a small-scaled distributed generation based on renewable energy, including solar energy, with their coordination control, has been modelled to ensure generation solvency and a demand response strategy based on load shifting technique using a demand response system (DRS) for demand-side proficiency.**

***Index Terms*—Computing, power demand, power generation, power systems, renewable energy.**

I. INTRODUCTION

Due to the escalating energy demand, the petroleum fuel crisis, environmental concerns, and global economic pressures, scientists and researchers must explore alternative resources for traditional power generation. [1, 2]

Renewable energy sources, such as solar energy, e.g., batteries, wind turbines, hydropower, and tidal power, offer the potential to meet a substantial portion of the growing demand while providing economic and environmental advantages over conventional energy sources. Therefore, it is highly recommended to adopt a combination of demand response and distributed generation based on renewable energy sources to fulfill requirements and ensure an efficient system [3-6].

This project aims to establish a feasible framework for demand response implementation utilizing predictive control techniques. The primary aim is to offer a diverse array of services facilitated by the Demand Response Mechanism that align with the requirements of power system management. With the progress made in this field, it becomes evident that the design and control architecture of the power system must be adjusted to address forthcoming challenges effectively. The main objectives are as follows;

- Manage temporary energy spikes and improve customer resilience and credibility.
- Reduces peak energy consumption in the hottest and coldest months, offsetting the need for expensive and contaminated equipment that operates only a few hours each year.
- Increase the flow of communication with customers regarding energy consumption and advisecustomers on other energy and cost management tools.
- To utilize maximum energy produced by renewable energy resource
- Enable the demand response mechanism to provide diverse services, including load shifting peakshaving, to address power system management effectively.
- Develop a dependable system that promptly and accurately responds to demand signals, ensuring seamless operation and minimizing downtime.
- Design the demand response mechanism to actively contribute to grid stability by mitigating electricity demand and supply fluctuations.
- Align the architecture with long-term sustainability goals, empowering a more intelligent and environmentally conscious energy ecosystem.

II. LITERATURE REVIEW

A. Background

The researcher can thoroughly understand the demand response and state-of-the-art renewable energy integration thanks to the literature review. The project can add to the information already known in the sector and find the most recent developments by evaluating academic articles, reports, and industrial publications. The researcher can pinpoint gaps or restrictions in the information available regarding demand response in power systems with a high proportion of renewable sources through the literature study [7-11]. The initiative can progress the discipline by highlighting areas needing additional research and identifying these gaps. An evaluation of various demand response implementation options that have been tried out or put forth in power systems abundant in renewable energy is made possible by reviewing the literature. The development of suitable DR frameworks can be aided by analyzing these tactics, revealing useful information about their efficacy, drawbacks, and advantages [1, 12-18]. The researcher might examine different technical approaches and tools to facilitate demand response participation in a literature review. This assessment can clarify whether these technologies are appropriate and feasible for integrating renewable energy sources. Understanding the laws and regulations that support demand response in power systems with a high proportion of renewable energy sources is essential. The literature review can evaluate the effects of current policies, find effective case studies, and recommend relevant changes to boost DR adoption [19-25].

A literature review can include case studies from actual demand response deployments in grids with a high renewable energy content. The difficulties encountered, the lessons discovered, and the real effects of demand response initiatives can all be learned from analyzing these situations. A thorough understanding of prior research and real-world experience is provided to the researcher through the literature review. With this knowledge, the FYP can better decide on the research's design, methodology, and prospective contributions [2]. The research described the design, development, and testing of an IoT-enabled smart stick intended to aid visually impaired people in navigating the outside environment while detecting and warning about obstacles [3]. The proposed solution used ultrasonic sensors to detect obstacles, a water sensor to detect puddles and wet surfaces, and a high-definition video camera with object recognition [4, 26-33].

Furthermore, in a comparable concept given by S. Subbiah, S. Ramya, G. Parvathy Krishna, and S. Nayagam, the user was warned of various impediments and objects via voice feedback delivered via e A solid theoretical framework for the FYP is built on the foundation of a well-structured literature evaluation. It aids in laying the theoretical foundation for the study and guarantees that the project is based on recognized ideas and principles. The literature review can also aid the selection of relevant research procedures and data-gathering strategies. It offers insights into the methodologies employed in earlier research and how well they work with the current project [5]. Demand response is the term for end-user customers' adjustments to their usual electricity to retain the same overall consumption. Use on-site generation. Customer sensitivity to and responsiveness to pricing signals rises due to demand response.

B. Preceding Experimentation

Demand response was considered a set of alternatives that Sezgen, Goldman, and Krishnarao may choose to exercise earbuds following accurate detection and identification of items [7] at a later time if necessary [8]. The customer viewpoints were considered while evaluating investments for load reduction, load shifting/displacement, and fuel replacement. These support the prediction and direction of consumer behaviour. It has been demonstrated that demand response increases the electrical market's effectiveness.

The former places a high importance on reliability, while the latter is more price-dependent. To illustrate the advantages of demand response, Khodaei et al. employed several case studies. According to their findings, demand response can "shave the peak load, reduce the system operating cost, reduce fuel consumption and carbon footprints, and reduce transmission load congestion by reshaping the hourly load profile." Demand response sensitive to price adds another layer of instability to the energy market and may hinder convergence. Zhao et al. investigated this using a non-iterative technique based on the contraction mapping theorem and a closed-loop iterative simulation technique [17-20]. It has yet to be demonstrated that the models offered to enable customer participation in the energy spot market are strong enough to resist the doubt of consumer behaviour in reaction to real-time price changes [9].

The predicted demand and generation accuracy would decrease if many consumers changed through various data. This would smooth out pricing variances. Roozbehani put forth a framework for modelling and examining the dynamics of source, claim, and clearing prices when customers are given real-time power pricing information [10]. According to the authors' theoretical study, new demand response technologies and storage may cause price volatility to grow under the way that the market and system are now operated [11].

To achieve these objectives efficiently, demand response proves to be a targeted approach, enabling the system to pay for curtailing electricity usage only when necessary to meet its goals [9]. Demand response has been extensively researched in the Wind and Renewables Integration context as a valuable tool for effectively integrating wind and other renewable energy sources. Wind's inherent can be effectively counterbalanced through swift and cost-effective demand response. Dietrich et al. conducted a study wherein they modelled specifically focusing on Gran Canaria, a small island in the Canary Islands [12]. They examined two scenarios: Demand Shifting, and Peak Shaving, wherein consumers independently respond to price signals. Instead of maximizing social welfare, the emphasis was on minimizing costs. The study's results showcased the cost savings achieved through demand-side management.

C. Integration of Energy Sources

Integrating renewable energy sources into power networks has significantly increased as the globe moves toward sustainable energy systems. However, the inherent erratic and variable nature of renewable energy sources challenges grid stability and balance. Demand response has emerged as a workable solution to these problems by actively incorporating users in the power grid's optimization. In an energy system predominately made of renewable sources, this literature review examines the status of knowledge and research on demand response.

Demand response, sometimes encouraged by time-based rates or financial advantages, is changing power consumption patterns in response to grid conditions. Researchers have thoroughly examined various DR strategies, such as price-based, incentive-based, and direct load control. With these systems, customers can help reduce or shift demand during peak hours, flattening the load curve and reducing grid stress [15-21]. Incorporating renewable energy sources like sun and wind into power systems has been the subject of numerous research. Renewable energy sources help to reduce carbon emissions, but their unpredictable nature makes it difficult for grid managers to maintain stability and guarantee a steady supply of electricity. This emphasizes the necessity of demand response as an additional strategy to balance supply and demand in a grid predominately comprised of renewable energy sources [22-28].

III. METHODOLOGY

Firstly, the power is supplied from WAPDA to ensure both loads can operate smoothly. The bulbs connected to Load 1 and Load 2 will illuminate, and the microcontroller's LCD will display the real-time current, voltage, and power readings. Next, we will switch the power source to a secondary option, which is a battery. The system will automatically switch to using the battery as its power source. As the system's demand changes, the battery's charge level will adjust accordingly. Consequently, the bulbs will gradually turn off, based on the system's requirements, while the system continues to operate within the battery's capacity. This setup ensures a seamless transition between the main power supply and the battery, allowing the system to run efficiently and effectively based on its power needs.

IV. EXPERIMENTAL WORK

After design implementation, we tested by dividing the project into modules.

The project was divided into the following sub-parts:

- Setting up the microcontroller, which was our Main Control Unit.
- Designing and Testing of VDR Circuit. Testing of Inverter.
- Testing of Transformer. Testing of Load 1 and Load 2. Testing of Battery.
- Testing of the complete circuit powered with battery and WAPDA.

A. Testing of Components

First, we implemented the Arduino code to check whether it was working properly. After that, we checked the working of the VDR circuit, which provided power to the Arduino. Then, the proper working of the inverter and transformer was checked to ensure it was converting 12V to 220V.

Finally, the complete working of Load 1 and Load 2 was checked on both Battery and WAPDA to check the efficiency of our project.

B. Testing of Inverter

To convert 12V, which was coming from Battery, we needed to test our Inverter, and for this purpose, we tested it many times to make sure it was converting 12V to 220V.

C. Testing of Load 1 and Load 2

First, we checked Load 1, which was our critical Load because first priority was given to it, and after that, we checked Load 2, which also consists of a Non-Critical Load, which could be turned on or off depending on the conditions.

D. Testing on BATTERY and WAPDA

In this part, we made sure that if WAPDA is coming, all of the loads can be used, but if WAPDA is cut off, the system will automatically be shifted on Battery and Non-Critical Loads will automatically be Turned off. This section is the user guide for the final product. It discusses all the features available in the product and how it functions, and it explains in very simple and basic words how to operate this product.

E. Installing the Arduino Code

First, we must upload the Arduino code we made to run the system properly. On the system, then we need to Turn ON our system through a switch to run it.

F. Turning on the WAPDA

After that, we need to connect the switch through the Main Grid (WAPDA) to check whether both Loads work fine.

G. Turning on the battery

At last, we need to connect the battery so that if WAPDA is cut off, our system will remain running, and everything will be shifted on the battery.

H. Enabling Load 1 and Load 2:

We have set Load 1 as a critical Load priority and will remain turned ON/OFF on both the battery and WAPDA. Still, Load 2 is to be turned OFF if the system is running on battery because it consists of Non-Critical Load, so it depends on the conditions.

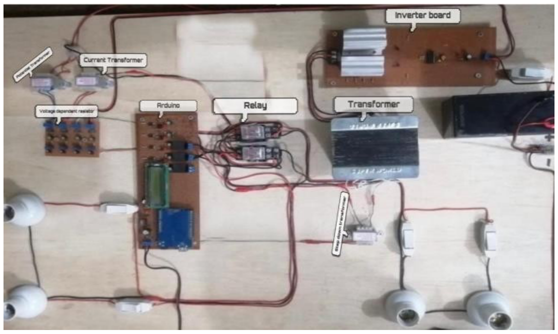

Figure 1: Final Functional Prototype

I. Detailed Hardware and Software Design:

Here are some of the primary hardware components utilized in the circuitry of the project:

- Inverter
- Battery
- Micro-Controller
- CT/PT
- Voltage Control unit
- Relay unit

Inverter:
Inverter is an electronic device that converts direct current (DC) into alternating current (AC). It is commonly used in various applications, such as solar power systems, uninterruptible power supplies (UPS), and electric vehicles. By reversing the polarity of the input power, inverters enable the efficient use of AC-powered devices and facilitate the transfer of electricity across different systems. Inverters are crucial in modern power conversion technology, offering flexibility and compatibility between DC and AC power sources [29-33].

Battery:
A battery is an electrochemical device that stores chemical energy and converts it into electrical energy. It consists of one or more cells connected together, capable of producing a direct current (DC). Batteries are commonly used in various applications, such as portable electronics, electric vehicles, and backup power systems. They provide a convenient and portable energy source for a wide range of devices, enabling them to operate without being directly connected to a power source.

Micro-Controller:
A microcontroller is a small integrated circuit that contains a processor core, memory, and input/output peripherals. It serves as the brain of many electronic systems, providing control and processing capabilities. Microcontrollers are commonly used in various applications, such as embedded systems, consumer electronics, and industrial automation. They offer a compact and cost-effective solution for performing specific tasks, with the ability to interface with various sensors, actuators, and communication modules. The versatility and programmability of microcontrollers make them essential components in developing innovative electronic devices and systems.

CT/PT:
Current Transformers (CT) and Potential Transformers (PT) are devices used in electrical power systems for measurement, protection, and control. CTs measure high currents by decreasing them to manageable levels, ensuring safe and accurate measurement. Conversely, PTs step down high voltage levels to a standard value for precise voltage measurement. Both CTs and PTs play critical roles in relaying accurate electrical data to instruments, protective relays, and control devices, ensuring efficient and reliable operation of power systems.

Voltage Control Unit:
A voltage control unit is an electronic device that regulates and maintains a specific voltage level within a circuit or system. It monitors the voltage and adjusts it to ensure stability and desired performance. The control unit typically includes voltage regulators and feedback mechanisms to achieve accurate voltage control. It plays a vital role in various applications to maintain consistent and reliable voltage levels, including power distribution systems, electronic equipment, and renewable energy systems.

Relay Unit:
A relay unit is an electromagnetic switch that controls the flow of electrical current in a circuit. It consists of a coil, an armature, and contacts. The armature moves when the coil is energized, allowing the contacts to open or close. Relays are commonly used in various applications for switching high currents, isolating circuits, providing electrical protection, and controlling different components in a system. They offer a reliable and efficient means of controlling power flow and enabling automation in various industries, including industrial automation, automotive systems, and power distribution.

Demand response in a renewable-dominated power system necessitates advanced load control algorithms to align with intermittent renewable generation. The system optimizes load management during response events by predicting energy and demand. It integrates renewable generation data to ensure the most efficient use of renewables. The software includes energy forecasting, demand prediction, and device control components. The control and communication layer coordinates modules and manages event scheduling. The system promotes grid stability and sustainability by efficiently balancing demand and renewable supply.

V. FINDINGS

Renewable Energy Variability Mitigation: Demand response programs have shown promising results in reducing the variability of renewable energy sources. DR reduced reliance on conventional power plants during periods of low renewable output by shifting electricity demand to times when renewable generation is high, ensuring a more stable and balanced power supply.

Variable Renewable Energy Integration:
Demand response was critical in integrating variable renewable energy sources such as wind and solar into the power system. DR enabled better coordination of energy consumption and renewable generation patterns, resulting in more efficient use of available renewable resources.

Peak Load Management: Demand response strategies effectively managed Pique electricity demand. DR reduced strain on the power grid by incentivizing consumers to adjust their consumption during peak hours, reducing the need for expensive peaking power plants and improving grid reliability.

Emissions of Greenhouse Gases Have Been Reduced: Demand response reduced greenhouse gas emissions by allowing for increased consumption during abundant renewable energy supply periods. As a result, the reliance on fossil fuel-based power generation during peak periods was reduced, resulting in a greener and more sustainable power system.

Cost Savings and Grid Stability: Demand response programs have resulted in significant cost savings for electricity consumers and utilities. Participants in DR programs benefited from lower electricity bills due to time-of-use pricing, while utilities benefited by avoiding costly infrastructure upgrades to meet peak demand. Furthermore, DR improved grid stability by providing a mechanism for dealing with sudden fluctuations in renewable energy output.

Customer Participation and Engagement: Consumer engagement and participation are among the most difficult challenges in implementing demand response. The study emphasized the importance of effective communication, education, and incentives to encourage consumers to participate actively in DR programs and maximize their impact on the power system.

VI. FUTURE PROSPECTS

New and more advanced demand response solutions will appear as the electricity system changes. Consider and incorporate cutting-edge demand response technology like smart appliances, home energy management systems, and thermostats. Examine their efficiency in boosting flexibility and demand response participation in a power system dominated by renewable energy sources. Investigate the use of demand response tactics in conjunction with dynamic pricing structures. Examine how time-of-use, real-time, and critical peak pricing affect consumer behaviour and demand response results. Analyze the advantages of maximizing energy consumption and lowering peak demand for consumers and the system [16]. Investigate how incorporating EVs into demand response systems can improve grid stability and aid the integration of renewable energy in light of the growing popularity of electric vehicles. Look at methods like vehicle-to-grid technology to enable two-way energy flow between EVs and the grid, enabling EVs to function as mobile energy storage units during periods of high demand. Add demand response in the commercial and industrial sectors to the research's expanded scope. Examine customized demand response solutions that consider these sectors' particular difficulties and potential as well as their distinctive energy usage patterns.

Analyze the legislative and policy frameworks that support demand response in power systems that rely heavily on renewable energy sources. Analyze the contribution of regulatory incentives, market structures, and government policies to implementing demand response and its fusion with renewable energy sources. Examine the effects of various incentive systems on demand response participation. Conduct behavioural analyses to comprehend customer motives and obstacles to demand response adoption. Create successful reward schemes that promote customer involvement and active participation in demand response initiatives [17].

In a power system with a high proportion of renewable energy sources and extensive use of demand response, cutting-edge simulation and modelling approaches are used to predict and assess future possibilities. Analyze the potential effects on the grid's stability, emissions reduction, and the energy system's overall efficiency. This Final year project can help advance knowledge of demand response's function in power systems that are dominated by renewable energy sources and offer insightful information for policymakers, business stakeholders, and consumers on how to maximize the advantages of clean energy integration while preserving a dependable and sustainable electricity grid by investigating these future research directions.

Effectively handle sudden surges in energy and enhance customer reliability and trustworthiness. Minimize high energy usage during extreme temperature months, thus eliminating the requirement for costly and polluting equipment that is only utilized for a few hours annually. Enhance communication channels with customers concerning energy consumption and offer guidance on additional tools for managing energy usage and costs [18]. Optimize the utilization of renewable energy resources by harnessing their maximum energy potential. Numerous projects have been undertaken in recent years, encompassing various hardware and software solutions to address the problem. However, despite the diversity of these projects, their fundamental working principles remain unchanged. A proposal has been made for a Demand Response controller that aims to efficiently coordinate the functioning of various household appliances [19]. Its objective is to minimize the consumer's electricity expenses, ensuring they remain below a predetermined threshold while maintaining comfort. Extensive advancements have been made in modelling home appliances.

VII. CONCLUSION

Finally, implementing demand response in a renewable-dominated power system holds enormous promise for addressing grid stability and variability and integrating renewable energy sources. Demand response, with its ability to shape electricity consumption patterns to align with renewable generation peaks, provides a versatile and effective solution for optimizing energy use, lowering emissions, and improving grid reliability.

As we move toward a renewable-dominated power system, the case for demand response becomes more compelling. Flexible demand management becomes critical with the increasing share of intermittent renewable sources such as solar and wind in the energy mix. Consumers can actively participate in the energy ecosystem through demand response mechanisms, transforming them from passive energy users to key stakeholders contributing to a cleaner and more sustainable future.

Demand response can alleviate grid strain during peak periods and prevent the curtailment of excess renewable energy by incentivizing consumers to shift their electricity consumption during periods of high renewable generation and low demand. Furthermore, demand response systems can play an important role in reducing reliance on fossil fuel-based backup power, enhancing the environmental benefits of renewable energy integration.

Collaboration among utilities, regulators, technology providers, and consumers is required to deploy demand response in a renewable-dominated power system successfully. Advanced metering infrastructure and smart grid technologies are critical to demand response program adoption. As we move toward a greener energy future, it is critical to recognize that demand response is not a stand-alone solution, but rather an essential component of a comprehensive approach to energy management. To ensure the seamless integration of renewables and the reliable operation of the power system, a combination of grid-scale energy storage, renewable energy forecasting, and demand-side management will be required.

In a renewable-dominated power system, implementing a demand response system is an innovative and effective way to address the challenges posed by intermittent renewable energy sources.

Demand response represents a significant step toward achieving a sustainable, low-carbon energy future by empowering consumers and utilities alike to adapt their energy consumption patterns to align with renewable generation. WAPDA serves as the primary power source, while the battery acts as a backup source. The inverter is linked to the Panel and facilitates the seamless switching between these two sources. A microcontroller is responsible for gathering data from the current transformer and potential transformer and processing it to generate a control signal. This signal is then transmitted to the voltage control unit and relay unit, enabling the smart switch to control the activation or deactivation of the loads.

Standardization plays a crucial role in bolstering the effectiveness of demand response initiatives. The Open DR standard is developing to support the necessary functionalities. This paper focuses on the optimized scheduling of flexible energy resources utilizing RTP. The primary goal of this optimization is to minimize the energy costs for residential end-consumers who possess an EV with vehicle-to-grid capabilities and three additional appliances. The aim is to achieve cost reduction without compromising comfort levels. The variation in RTP prices depends on the system's condition, and the end-consumers energy consumption, determined by the optimized scheduling, is influenced by RTP. As a result, consumers indirectly contribute to system stability and quality improvement by reducing their load during higher price periods and shifting it to lower price periods.

REFERENCES

[1] Environmental Protection Agency. (2015). Clean Power Planfor Existing Power Plants Clean Power Plan | US EPA.[Online]. Accessed on 30th September 2015.

[2] Oh, H. S., & Thomas, R. J. (2008). Demand- Side Bidding Agents: Modeling and Simulation. IEEE Transactions on Power Systems, 23(3), 1050-1056.

[3] Su, C. L., & Kirschen, D. (2009). Quantifying the Effect of Demand Response on Electricity Markets. IEEE Transactions on Power Systems, 24(3), 1199-1207.

[4] Kirschen, D. S. (2003). Demand-Side View of Electricity Markets. IEEE Transactions on Power Systems, 18(2), 520-527.

[5] Dietrich, K., Latorre, J. M., Olmos, L., & Ramos, A. (2012). Demand Response in an Isolated System with High Wind Integration. IEEE Transactions on Power Systems, 27(1), 20-29.

[6] Zhao, C., Wang, J., Watson, J. P., & Guan, Y. (2013). Multi-Stage Robust Unit Commitment Considering Wind and Demand Response Uncertainties. IEEE Transactions on Power Systems, 28(3), 20- 29.

[7] Wu, H., Shahidehpour, M., & Khokayar, M. (2013). Hourly Demand Response in Day- Ahead Scheduling Considering Generating Unit Ramping Cost. IEEE Transactions on Power Systems, 28(3), 2446-2454.

[8] Pourmousavi, S. A., & Nehrir, M. H. (2014). Introducing Dynamic Demand Response in the LFC Model. IEEE Transactions on Power Systems, 29(4), 1562-1572.

[9] Papdaskalopoulos, D., & Strbac, G. (2013). Decentralized Participation of Flexible Demand in Electricity Markets – Part I: Market Mechanism. IEEE Transactions on Power Systems, 28(4), 3658-3666.

[10] Papdaskalopoulos, D., Strbac, G., Mancarella, P., Aunedi, M., & Stanojevic, V.

[11] (2013). Decentralized Participation of Flexible Demand in Electricity Markets – Part II: Application With Electric Vehicles and Heat Pump Systems. IEEE Transactions on Power Systems, 28(4), 3667-3674.Nguyen, D. T., Negnevitsky, M., & de Groot,

[12] M. (2011). Pool-Based Demand Response Exchange – Concept and Modeling. IEEE Transactions on Power Systems, 26(3), 1677-1685.

[13] Zhao, Z., Wu, L., & Song, G. (2014). Convergence of Volatile Power Markets With Price- Based Demand Response. IEEE Transactions on Power Systems, 29(5), 2107- 2118.

[14] Roozbehani, M., Dahleh, M. A., & Mitter, S.

[15] K. (2012). Volatility of Power Grids Under Real-Time Pricing. IEEE Transactions on Power Systems, 27(4), 1926-1940.

[16] Papavasiliou, A., & Oren, S. S. (2014). Large-Scale Integration of Deferrable Demand and Renewable Energy Sources. IEEE Transactions on Power Systems, 29(1), 489-499.

[17] Rabiee, A., Soroudi, A., & Mohammadi- ivatloo, B. (2014). Corrective Voltage Control Scheme Considering Demand Response and Stochastic Wind Power. IEEE Transactions on Power Systems, 29(6), 2965- 2973.

[18] Madaeni, S. H., & Sioshansi, R. (2013). Measuring the Benefits of Delayed Price- Responsive Demand in Reducing Wind-Uncertainty Costs. IEEE Transactions on Power Systems, 28(4), 4118-4126.

[19] Madaeni, S. H., & Sioshansi, R. (2013). Using Demand Response to Improve the Emission Benefits of Wind. IEEE Transactions on Power Systems, 28(2), 1385- 1394.

[20] Zeng, B., Zhang, J., Yang, X., Wang, J., Dong, J., & Zhang, Y. (2014). Integrated Planning for Transition to Low-Carbon Distribution System With Renewable Energy Generation and Demand Response. IEEE Transactions on Power Systems, 29(3),

1153- 1165.

[21] D. Burns, T. Bialecki, G. Gil, D. Kathan, P. Lee, Michael, S. Peirovi, and R. Puram, "2020 assessment of demand response and advanced metering," FEDERAL ENERGY REGULATORY COMMISSION, Tech. Rep., 2020.

[22] J.-x. Wang, X.-f. Wang, and X.-l. Wang, "Study on model ofinterruptible load contract in power market," PROCEEDINGS-CHINESE SOCIETY OF ELECTRICAL ENGINEERING, vol. 25, no. 9, p. 11, 2005.

[23] A. Tiwari and N. M. Pindoriya, "Optimal scheduling of home appliances under demand response," in 2020 21st National Power Systems Conference (NPSC). IEEE, 2020, pp. 1- 6

[24] Muhammad Nasir Khan, Syed K. Hasnain, Mohsin Jamil, Sameeh Ullah, "Electronic Signals and Systems Analysis, Design and Applications International Edition," in Electronic Signals and Systems Analysis, Design and Applications: International Edition, River Publishers, 2020

[25] Khan, Muhammad Nasir, Hasnain Kashif, and Abdul Rafay. "Performance and optimization of hybrid FSO/RF communication system in varying weather." Photonic Network Communications vol. 41, no. 1, pp. 47- 56, 2021.

[26] Jamil, Mohsin, Muhammad Nasir Khan, Saqib Jamshed Rind, Qasim Awais, and Muhammad Uzair. "Neural network predictive control of vibrations in tall structure: An experimental controlled vision." Computers & Electrical Engineering, vol. 89, pp. 106940, 2021.

[27] Khan, Muhammad Nasir, Mohsin Jamil, Syed Omer Gilani, Ishtiaq Ahmad, Muhammad Uzair, and H. Omer. "Photo detector-based indoor positioning systems variants: A new look." Computers & Electrical Engineering, vol. 83, pp. 106607, 2020.

[28] Kashif, Hasnain, Muhammad Nasir Khan, and Ali Altalbe. "Hybrid optical-radio transmission system link quality: link budget analysis." IEEE Access, vol. 8, pp. 65983-65992, 2020.

[29] Khan, Muhammad Nasir, and Fawad Naseer. "IoT based university garbage monitoring system for healthy environment for students." In 2020 IEEE 14th International Conference on Semantic Computing (ICSC), pp. 354-358. IEEE, 2020.

[30] Uzair, Muhammad, R. O. B. E. R. T. D DONY, Mohsin Jamil, KHAWAJA BILAL AHMAD MAHMOOD, and Muhammad Nasir Khan. "A no-reference framework for evaluating video quality streamed through wireless network." Turkish Journal of Electrical Engineering & Computer Sciences, vol. 27, no. 5, pp. 3383-3399, 2019.

[31] Khan, Muhammad Nasir, Syed Omer Gilani, Mohsin Jamil, Abdul Rafay, Qasim Awais, Bilal A. Khawaja, Muhammad Uzair, and Abdul Waheed Malik. "Maximizing throughput of hybrid FSO-RF communication system: An algorithm." IEEE Access, vol. 6, pp. 30039-30048, 2018.

[32] Khan, Muhammad Nasir, Syed K. Hasnain, and Mohsin Jamil. Digital Signal Processing: A Breadth-first Approach. Stylus Publishing, LLC, 2016.

[33] Khan, Muhammad N. "Importance of noise models in FSO communications." EURASIP Journal on Wireless Communications and Networking vol. 2014, no. 1, pp. 1-10, 2014.