## Submission of Research Objective

1. **Research Objective (Topic):** Design and Development of a Smart Device with built-in Real Time-of-use Tariff-based Demand Side Management Controller.
2. **Lead of project-GM and above**:
3. **Co-Ordinator of Project**: Sh. Alok Pratap Singh, Chief Manager (SO)
4. **Key Problem Areas**:

In an era where electricity consumption, operational efficiency, and unit cost are significant concerns, optimizing multiple parameters is essential to derive maximum benefits from existing systems. Dynamic pricing, for example, can significantly impact energy costs with simple changes in time-of-use, making it critical to modulate loads based on real-time pricing and load characteristics. These challenges underscore the need for smarter energy management strategies that balance operational efficiency with economic sustainability.

Smart energy management is vital for achieving Smart Grid objectives and economic goals. While blockchain-based frameworks for transmission-level management exist, challenges persist at the distribution level. Accurate load characteristics, essential for energy management, can be obtained through meter readings or advanced tools like artificial intelligence and data analytics. However, handling large-scale data and ensuring accuracy pose challenges.

Protecting consumer privacy is a cornerstone of smart load management. Ensuring data privacy compliance is key to gaining consumer acceptance, without which adoption is unlikely. Coordinated demand management and synchronized load measurements are essential for controlling multiple resources, including distributed generators. However, the absence of such integration affects grid efficiency and resource utilization. Advanced technologies like IoT, 5G, and 6G, while promising, face technical and economic hurdles in their integration.

This project proposes the following objectives:

Stage-I

a. To design and develop a smart device that is capable of connection/disconnection of load.

b. To design and develop a smart controller which is capable of making decisions about connection/disconnection of load based on the type of load, necessity of load, time-of-use of load, and real price at time-of-use.

c. To infuse the capability of making smart decisions based on externally sensed inputs, like ambient conditions of rainfall, humidity, isolation, temperature, and manual inputs.

d. To develop a smart decision-making system with the help of Artificial Intelligence and Data Analytics, so as to make the device future-ready.

e. To integrate the developed smart device and the controller along with the network of devices, so as to achieve a Smart Demand Side Management.

f. To validate the developed system on a pilot scale*.

*To collaborate with State Load Dispatch Centers (SLDCs) to implement the developed methodology at the state level. This phase focuses on deploying the smart demand-side management system in real-world scenarios, enabling seamless integration with state-level operations while addressing region-specific challenges and ensuring scalability

Establishing a future-ready system capable of controlling load consumption through real-time data processing and external inputs, supported by Artificial Intelligence for decision-making and Data Analytics for enhanced load modelling, aims to optimize energy use, improve efficiency, and support Smart Grid goals while addressing technical, social, and privacy challenges.

## 5. METHODOLOGY OF RESEARCH:

- As this project proposes to develop multiple sub-products and integrate them into a Smart Demand Management System, a critical analysis of existing systems, if any, is to be conducted. A smart device that can interface with each load in the premises and is capable of connecting or disconnecting with mains—individually, in groups, or all loads together—is to be developed. This device is to play a pivotal role in achieving the desired objectives. Its functionality is to be governed by factors such as the type of load, the necessity of load, the time-of-use, and the real-time price of electricity.

- Since the developed device is central to achieving the desired objectives, it is to be equipped with enhanced intelligence. This is to be achieved by integrating a smart decision-making capability, facilitated by a controller that processes externally sensed inputs such as ambient conditions (rainfall, humidity, isolation, and temperature) as well as manual inputs.

- To realize the objectives of Smart Demand Side Management, it is essential to integrate the developed device with the controller. This integration is to involve a network of devices, loads, sensors, and other components, enabling an adaptive and interactive decision-making process. This approach is to ensure the system aligns with the preferences and requirements of various stakeholders while exerting effective control over energy consumption.

- This is to provide insights into real-world performance and facilitate necessary refinements.

## 6. IMPLEMENTATION PLAN:

- ERLDC, GRID-INDIA may engage any industry/institution as consultant for the project.

- The engaged consultant /institution shall prepare a detailed scope, roadmap and deliverables for the research project.

- As per consultant recommendations, necessary hardware/ infrastructure and software tools/licenses shall be procured for GRID-INDIA.

- Testing and acceptance can be done jointly by the engaged institution/ consultant and GRID-INDIA.

- The project can have many stages and Stage wise payment can be made to engaged consultant/institution as per target achieved.

## 7. Citation/References (Relevant Literature/Technical Papers):


1. M. H. Raza, Y. M. Rind, I. Javed, M. Zubair, M. Q. Mehmood and Y. Massoud, "Smart Meters for Smart Energy: A Review of Business Intelligence Applications," in IEEE Access, vol. 11, pp. 120001-120022, 2023, doi: 10.1109/ACCESS.2023.3326724

2. H. -T. Zhang et al., "Power Network Smart Meter Data Driven Cross-Task Transfer Learning for Resident Characteristics Estimation," in IEEE Journal of Emerging and Selected Topics in Industrial Electronics, vol. 5, no. 2, pp. 652-661, April 2024, doi: 10.1109/JESTIE.2024.3350537

3. D. Li, Q. Yang, F. Zhang, Y. Wang, Y. Qian and D. An, "Research on Privacy Issues in Smart Metering System: An Improved TCN-Based NILM Attack Method and Practical DRL-Based Rechargeable Battery Assisted Privacy Preserving Method," in IEEE Transactions on Automation Science and Engineering, vol. 21, no. 3, pp. 2882-2899, July 2024, doi: 10.1109/TASE.2023.3270543

4. C. Hu, Z. Liu, R. Li, P. Hu, T. Xiang and M. Han, "Smart Contract Assisted Privacy-Preserving Data Aggregation and Management Scheme for Smart Grid," in IEEE Transactions on Dependable and Secure Computing, vol. 21, no. 4, pp. 2145-2161, July-Aug. 2024, doi: 10.1109/TDSC.2023.3300749

5. Z. Zhao, G. Liu and Y. Liu, "Practical Privacy-Preserving Electricity Theft Detection for Smart Grid," in IEEE Transactions on Smart Grid, vol. 15, no. 4, pp. 4104-4114, July 2024, doi: 10.1109/TSG.2023.3349280

6. R. Morello, G. Fulco, S. Mukhopadhyay, L. Fabbiano and C. De Capua, "Time Synchronized Power Meters for Advanced Smart Distribution of Energy in Smart Grids," in IEEE Sensors Journal, vol. 24, no. 19, pp. 30909- 30919, 1 Oct.1, 2024, doi: 10.1109/JSEN.2024.3445494

7. M. U. Saleem, M. R. Usman, M. A. Yaqub, A. Liotta and A. Asim, "Smarter Grid in the 5G Era: Integrating the Internet of Things With a Cyber-Physical System," in IEEE Access, vol. 12, pp. 34002-34018, 2024, doi: 10.1109/ACCESS.2024.3372379