RESEARCH PROPOSAL

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By Smart Systems Research Group

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IMOLEDE

SMART SOLAR ENERGY DEVICE AND MANAGEMENT SYSTEM

1. Brief description of the innovation

The ImoleDe Smart Solar Energy Management System is designed to optimize solar inverter system performance and extend system longevity through intelligent energy management techniques. This innovative product combines real-time remote monitoring, intelligent load prioritization, and smart control using sensors, a mobile application, and AI algorithms, with the goal of enhancing the user experience and ensuring reliable power management in solar installations.

With a GDP of approximately $448 billion, Nigeria is the largest economy in sub-Saharan Africa, estimated at over 220 million people. With only about 60% electrification, Nigeria falls behind comparable sub-Saharan countries like Ghana (83%) and Kenya (64%) in electrification rate. The Government of Nigeria, over the years, has invested billions of dollars in improving the electricity supply and privatizing the sector to assist it in reaching more efficiency. Unfortunately, progress has been slow. About 8.8 million Nigerians currently have no access to electricity and only 66% of those who have electricity have an average of 5 hours per day. Nigeria provides presently 0.04% of the required 4000kWh annual per capita electricity consumption per person needed to reach energy self-sufficiency and sustainability [1,2,3].

This has dramatically affected the country's economic development. Renewable energy systems offer new possibilities for areas with low or unreliable electricity access. An added advantage is that Nigeria receives an estimated 3.5 - 7.0 kWh/m2/day of solar installation for optimal photovoltaic (PV) electrification and has one of the shortest project lead times in power generation projects [4].

From literature, 10.5 million Nigerians have inverter-based energy system. This market is one of the fastest growing markets in Nigeria with a growth rate of 38% in 2022, 628,000 additional sales. Unfortunately, even with the influx of this alternative energy supply, electricity is not available because generation and storage is not adequately monitored and managed. There are limited ways for users to monitor, control, manage, and optimize the usage of energy generation and storage [5,6].

Energy storage is a basic part of the renewable solar energy system because, it defines backup time, availability and life-span of the system. Most users have no control over the management of the

inverter system and, therefore, sub-optimal use of expensive installations and investment. Existing solutions addressing the problems of monitoring, control and management of existing inverter system with and without solar panels are the timers and remote monitoring for feedback and manual control.

Timers are add-on device for cutting off energy to individual load on the inverter installations and the drawbacks are: limited adaptability; lack of real-time data and control coupled with limited; and high potential for user error

Another solution is the remote monitoring of the energy storage and, with received information, the user manually switches off or on devices based on information: limited adaptability; Manual control; and high potential for user error

1.1 Particular problem Innovation addresses or solves.

ImoleDe is a non-intrusive smart energy management system to help home owners and businesses monitor, control, and optimize their energy usage with the help of sensors, mobile app and artificial intelligence for real-time load prioritization from anywhere in the world. It promises smart analysis, control with AI and a good return on investment. Table 1 presents our solution and challenges addressed.

Table 1: Challenges addressed by our solution

Challenges addressed by our solution	Our Solution
Unavailability of electricity when needed	Electricity is available when needed
Battery storage is not available when needed	Battery storage is controlled automatically to ensure availability at specified time.
Lack of feedback and information about inverter installation	Monitoring, control, and management of the inverter system is available to the user
Professional installation	Self-installation
Unpredictable failure due to reduction in the storage capacity of the batteries	Prior knowledge to enable proper budgeting
Manual control and management	Automated prioritization of load
Lack of information and professional know-how	Artificial intelligence control and management to ensure optimal use of the installation

Our solution is a smart solar system management solution that extends the lifespan of solar inverter systems. It uses smart technologies to help users reliably meet their energy needs by providing real-time information and load prioritization through manual or automated control.

The ImoleDe system:

a. significantly increase the lifespan of solar inverter systems, improve battery performance,
b. provide users with real-time data and control capabilities over their energy usage
c. the system helps users optimize their energy resources by remotely monitoring grid status, battery charge levels, inverter performance, and solar panel output, while also ensuring that critical loads are prioritized
d. allow for efficient energy consumption, especially during power outages, peak sunlight periods, and peak usage periods, ensuring that essential devices stay operational.

ImoleDe Solar energy Solution can

1. seamlessly integrate with existing solar energy system setups, eliminating the need for costly full-system upgrades.
2. monitor, control, optimize and manage the solar energy system on-site and remotely through an intuitive mobile application, providing real-time data and easy access.
3. prioritize load usage based on user preferences, state of charge of the batteries, weather conditions and the size of load considered.
4. monitor energy generation and consumption, allowing users to track solar energy installation performance to make informed decisions.
5. be integrated into any existing solar energy system setup and it can also be incorporated into new installation

   Our solution

6. is affordable and designed with Nigeria's peculiar financial, climatic and users in mind. It is Nigerian focused and oriented
7. It incorporates existing solutions such as time-control, surge protection and remote monitoring and further incorporating the unique feature (1-6). Therefore, giving users an optimal usage of the solar energy system installation in terms of user satisfaction, usage at

any time and any device needed, longevity and seamless management of their solar energy installations.

2. Societal and economic benefits of innovation

From literature, 10.5 million Nigerians have inverter-based energy system. This market is one of the fastest growing markets in Nigeria with a growth rate of 38% in 2022, 628,000 additional sales. Unfortunately, even with the influx of this alternative energy supply, electricity is not available because generation and storage is not adequately monitored and managed. There are limited ways for users to monitor, control, manage, and optimize the usage of energy generation and storage [5,6].

The innovation aligns with Sustainable Development Goal 7 - ensures access to affordable, reliable, sustainable and modern energy for all. Lack of access to energy supplies and transformation systems is a constraint to human and economic development. Furthermore, energy efficiency and increase use of renewables contribute to climate change mitigation and disaster risk reduction, thereby maintaining and protecting ecosystems.

With only 45% of Nigeria's population has access to electricity, with significant disparities between urban and rural areas (Source: World Bank).

ImoleDe brings an option of efficiency and improved availability of energy supply to consumers during their time of need as a necessity and this can bring numerous societal and economic benefits. These include: improved standard of living, increase in GDP per capita, increase in life expectancy, improved standard of life, higher human development index (HDI), and increased productivity and job creation.

2.1 Improved Standard of Living

Access to modern energy services is a critical component of standard of living. According to the International Energy Agency (IEA), in 2020: 89% of the global population had access to electricity and 34% of the global population had access to clean cooking fuels and technologies [7].

2.2 Increase in GDP per capita

Energy access is also strongly correlated with GDP per capita of a Country. According to the World Bank, in 2020: countries with high energy access (above 90%) had an average GDP per capita of $14,333. While countries with medium energy access (50-90%) had $4,333. Countries with low energy access (below 50%) had an average GDP per capita of $1,444 [8].

2.3 Increase in Life Expectancy

Energy access is also correlated with life expectancy. According to the World Health Organization (WHO), in 2020: Countries with high energy access (above 90%) had an average life expectancy of 77.4 years, while countries with medium energy access (50-90%) had an average life expectancy of 69.4 years. Countries with low energy access (below 50%) had an average life expectancy of 61.4 years [9].

2.4 Improved Standard of Life

Electricity consumption is a key indicator of standard of life. According to the IEA, in 2020: The average electricity consumption per capita in high-income countries was 12,143 kWh, 2,444 kWh for middle-income countries and 444 kWh low-income countries [7].

2. 5 Higher Human Development Index (HDI)

Human Development Index (HDI) is a composite index measuring standard of life. According to the United Nations Development Programme (UNDP), in 2020: countries with very high HDI (above 0.8) with average electricity consumption per capita of 10,333 kWh. 4,444 kW for countries with high HDI (0.7-0.8) and 1,777 kWh for countries with medium HDI (0.5-0.7) [10].

2.6 Increased Productivity and Job Creation

Reliable energy supply can increase productivity by 20% and improve competitiveness by 15% . It can alsocreate up to 100,000 jobs in the energy sector (Source: Nigerian Ministry of Power). Only 45% of Nigeria's population has access to electricity, with significant disparities between urban and rural areas [11].

3. Brief description of the engineering processes that it covers.

3.1 Introduction

The ImoleDe system consists of several hardware components, including sensors that measure battery voltage, solar panel output, grid AC voltage, and inverter output. The system is housed in a

sturdy, compact casing that can be mounted on a wall near the inverter installation. It handles up to 50A of current and supports systems up to 10KVA.

3.2 Design

The Design has the following subsystems: Battery Charge Monitor, Battery Discharge Monitor, Grid Monitor, System Loading Monitor, Load Switching System, Central Hub/Controller, Mobile Application and a Server for administrative and AI analysis purposes. The high level architecture system is shown in Figure 1.

Dataflow, use case and activity diagrams are saved in the folder. Data flows into the hardware device through sensors and the mobile application. The microcontroller carries out some energy data estimations and sends the information to the relays to switch off/on based on priority and selected loads. The microcontroller also sends information to the mobile application on energy use and energy generation. It also receives control data from the mobile application.

Data is also sent to a database server for the purpose of data gathering for more informed decisions using AI enabled assistance in the control and optimized management of energy use in the buildings where ImoleDe devices are installed. Figure 2 shows the data communication diagram, communication will be through wireless and wired methods.

Energy comes into the house through two major sources: the mains supply and the solar inverter system. The microcontroller selects the mains supply by default to provide electricity to the house. When the mains is not available or the voltage supplied from the mains is below a set threshold, the Solar Inverter System and the ImoleDe system kicks in. The ImoleDe management system selects prioritised loads to be switched on from the switching module. It also communicates control and monitoring information through the communication module mobile application.

The entire system is self-contained in a metallic container box of not more than 15 square inches for easy installation. All connector interfaces such as terminal block, USB and ethernet port are placed on the lower exterior part of the container for easy access. The container also features a display on the front facing side to enhance user experience. All sensors, microcontroller, modem, accompanying electronics and breakers are spatially arranged to ensure heat management since the system is air cooled. Vents and miniature pores are placed on the four sides of the container box to facilitate heat dissipation which must be as minimal as possible.

4. Degree of development of the prototype (how far has it been developed)

ImoleDe's functional prototype is ready and the researchers are looking for funding to move too the next phase of first adopters evaluation, standard organization certification, commercialization and market ready products and presently at technology readiness level (TRL) 7.TRL 7 - System Prototype Demonstration in an Operational Environment: Design, development and lab testing of components/processes. Technology is demonstrated in an operational environment.

5. Sketches, photographs, drawings and other illustrations that can aid the understanding of innovation

5.1 Installation and Usage Instructions

The ImoleDe system is designed for ease of installation by a qualified technician. It connects to solar panels, the inverter, battery, and mains supply and delivers its output to the building's distribution board. With minimal documentation, installation is straightforward, with the device able to handle the entire power flow from the solar system to the home's electrical infrastructure.

Once installed, users can configure the system using the mobile application. The app guides users through the setup process, including load prioritization, remote control, and energy monitoring. Advanced users can set schedules or automate energy management through the app's AI-driven features, optimizing energy distribution based on real-time conditions.

6. Profiles of Team

sign. Charles, with a background in Information and Communication Engineering, contributes with his knowledge of wireless and mobile connectivity. Olayiwola, also a Computer Engineer, focuses on cloud integration and app development, ensuring seamless user experience and reliable remote control.

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