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Development of Microgrids for Rural Electrification in India: The Case of Keonjhar

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1. Introduction

As of 2024, India has been making significant strides in renewable energy development. India has made considerable progress in solar energy, aiming to expand its capacity significantly. The country has become one of the largest solar markets globally, with large-scale solar farms and rooftop installations growing rapidly. As of mid-2024, India's installed solar capacity is over 70 GW, with plans to reach 100 GW by 2030. India is also a major player in wind energy. The installed wind power capacity is nearing 40 GW. The government continues to support the sector through various policies and incentives, including repowering old wind farms to increase their efficiency. Biomass energy is being harnessed from agricultural and industrial waste. The installed capacity is around 10 GW, and there are ongoing projects to enhance this by converting organic waste into energy.

The Indian government continues to push for renewable energy through policies like the National Solar Mission, the Wind-Solar Hybrid Policy, and various incentives for clean energy investments. There's a strong focus on integrating renewable energy with the grid and improving energy storage solutions. India is also engaging in international partnerships to advance its renewable energy goals. For example, it is a member of the International Solar Alliance (ISA), which aims to promote solar energy globally. Overall, India is on a robust path to expanding its renewable energy infrastructure, aligning with its commitment to reducing carbon emissions and increasing the share of renewables in its energy mix.

India has made significant progress in rural electrification and the development of microgrids over the past decade. Several rural electrification schemes have been implemented by the Government of India (GoI). Moreover, to encourage micorgrids and effective utilization of renewable energy, GoI has engaged in partnerships with international organizations for funding and technical support. Once such initiative is the EU-India Clean Energy and cooperation in energy research and innovation, in particular related to renewable energy and its integration in the energy system.

Renewable Energy EMPOWERing European and InDian communities (RE-EMPOWERED) is the project sanctioned under this program by GoI and EU. The aim is to develop a set of solutions (ecoToolsets) for efficient, de-carbonized and RES-intensive multi-energy local energy systems. The solutions of the toolset have been tailored to the

specific needs of four pilot cases in India and EU but will aim at a wide target group for replication and exploitation in both the developed and developing world. In this article, the development of the microgrid in Keonjhor in India is presented.

2. Background of Keonjhor Demo Site:

Kanheigola, Nola and Ranipada are small Villages/hamlets in Harichadanpur-Tehsil reserve forest in Keonjhar District of Odisha State, India. They are located 54 km towards South from District headquarters Keonjhar and 180 km from state capital Bhubaneswar. At present these villages are not connected to the main utility grid. This site is ideal as a demonstration site as it already has some basic renewable energy facilities. These have been upgraded and coupled with various available energy vectors to improve the living standards of the community.

A total of 77 kWp Solar PV installations have been supplied to approximately 1000 villagers, living in 306 households, installed by Odisha Renewable Energy Development Agency (OREDA) in 2017-18. Every house in these villages is provided with 100 W for meeting the basic facilities like 2 tube lights and fans only during nighttime. The village includes one high school and one primary school, a primary health care centre. The main source of income is agriculture (mainly rice) in which 80-90% of people are involved. The water from downstream is the major source for cultivation. Very limited commercial establishments such as rice huller machines are present which are run by a diesel engine.

Figure 1: Location of Keonjhar demo site

3. Installation of 50 kWp Microgrid:

The installation of the new 50 kW microgrid aims not only to meet household demand, but also to establish ecosystems for the utilization of energy for income-generating purposes in agriculture and small businesses. Ultimately, this initiative aims to reduce rural-to-urban migration. Furthermore, in support of businesses and agriculture, electric vehicles are supplied for transportation to sustain the supply chain.
The project has upgraded the existing infrastructure through indigenously developed technology by deploying secondary 50kW micro grid comprising various renewable energy vectors, namely:

- A 30 kWp PV plant with 56 modules in a series-parallel arrangement—14 modules in series and 4 strings in parallel.
- A 10 kW biomass plant consisting of a gasifier to convert biomass into gas, a blower to ensure proper gas flow, a cooling tower and the engine-generator set with connection pipes and filters
- A 10 kW biogas plant with a digester for processing cow dung, a mixing tank, and a Y-junction for directing the flow. The biogas produced is stored in a balloon and purified before being used by the engine-generator set to produce electricity.
- A battery energy storage system composed of 120 battery cells connected in series, providing a total voltage of 240V and a storage capacity of 180 kWh.

Figure 2 describes the block diagram of the newly developed microgrid along with RE-EMPOWERED deployed ecotools. The mircogrid is equipped with the following features:

- advanced energy management system (ecoMicrogrid).
- Charging infrastructure for commercial three-wheelers, especially designed to fulfil the local needs of the community.
- Smart meters with load limiter and load management functionalities.
- IoT based remote measuring system.
- Solar dimmable streetlights with configurable brightness, in order to save energy ensuring public safety.

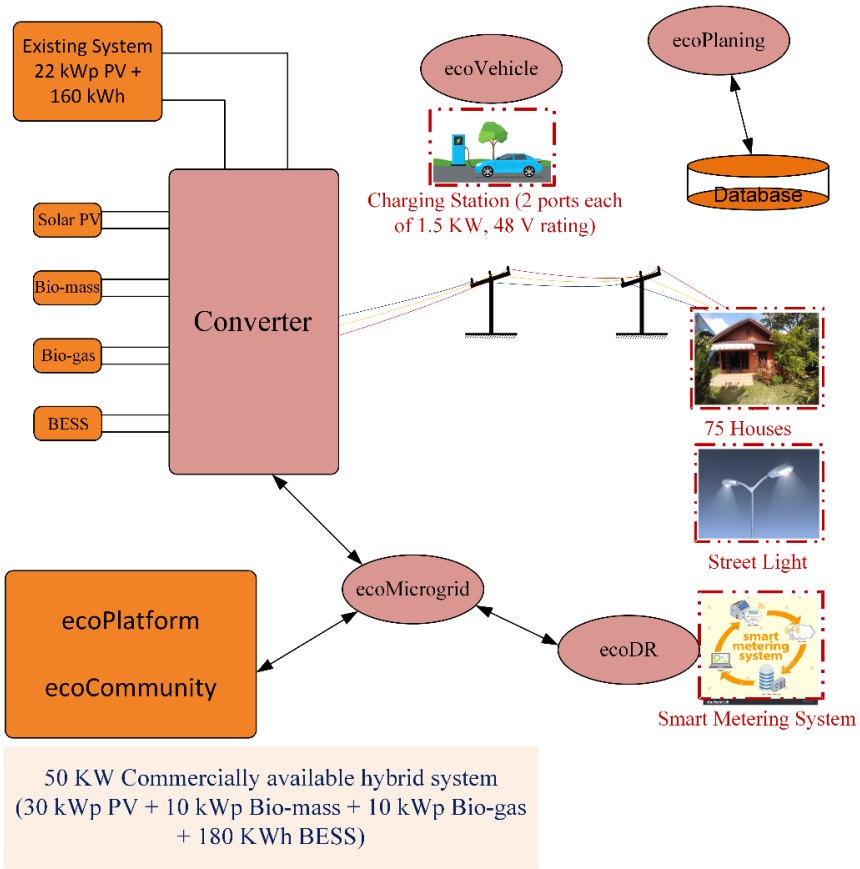

Figure 2: Block diagram of new 50 kWp microgrid

The installation of the multi vector microgrid has been started in the year 2023. All the four energy vectors have been successfully installed and the villagers are provided with power from the newly developed microgrid for extended hours of operation.

4. RE-EMPOWERED tools

4.1 Deployment of ecoMicrogrid

The deployment of the ecoMG tool at the Keonjhar Demo Site is specifically tailored to the electrical vector. It includes the following functionalities:

- Energy Optimization
- Consumption and Production Forecast
- Demand Response Functionalities
- SCADA visualization
- Integration with Other ecoTools

4.2 Deployment of ecoVehicle

The ecoVehicle tool deals with transportation electrification including e-three wheelers and the charging infrastructure. The e-three wheelers are modified and customized in such a way that they can carry only goods when there are fewer passengers and vice versa. The motor capacity has been enhanced to 2 kW and the associated drive train is modified. Charging points receiving energy from islanded grid have been installed. Each of the deployed chargers is 3.3kW and the off-sun hour support is around 5 hours with 50% depth of discharge of the battery energy storage (BESS) system.

Figure 4: EV loader and charging station

4.3 Deployment of ecoDR

The ecoDR is an advanced smart meter with innovative features to enhance energy management and control. At the demo site, a number of 10 ecoDRs have been deployed to monitor & control the entire energy consumptions for all the village houses connected with the specific meters and are used for proper load distribution. As the distances are long between the smart meters and control room, a cost-effective RF communication based system is installed to establish the communication link.

4.4 ecoCommunity

The ecoCommunity tool encourages community involvement in microgrid operations by providing real-time and historical consumption data, variable pricing and status indicators, and tools for load management and coordination. Users can adjust their energy usage based on these data, optimize costs by connecting non-critical loads during low-price periods, and maintain microgrid stability by disconnecting non-essential loads when necessary. The tool also allows for coordinated use of communal loads, supports easy digital payments, and offers a platform for reporting issues, seeking help, and sharing feedback within the energy community.

4.5 ecoPlatform

The EcoPlatform is an advanced integration tool designed to facilitate seamless communication and data exchange between various ecoTools within an installation site. It leverages a Dockerized architecture to ensure modularity, security, and ease of deployment across different environments. The platform comprises key subsystems including the Enterprise Service Bus (ESB), a centralized Database, a Storage Microservice, an API for data visualization, and a user-friendly Front-end Dashboard.

(a)

(b)

(c)

(d)

(e)

Figure 2: (a) 30 kWp solar PV installation (b) Control room with 180 kWh BESS (c) Biogas digester (d) Bio-mass and biogas engines (e) Bio-mass plant

5. Formation of Local Energy Community:

The success of this system depends on the active cooperation of the local population, which has been trained to manage and maintain the technologies. The co-operative Society of Keonjhar called **"Ranipada Grama Shakti Samuha",** has been formed in 2023. The members of the society are trained to handle the basic maintenance of the microgrid and day to day activities. A community bank account has been opened to manage the financial aspects of the energy infrastructure. The funds collected through electricity charges and other sources will be used for maintenance and other operational costs.

(a) *(b)*

Figure 6: (a) Flow-chart to show the action plan for technology/asset transfer (b) Community Meeting with Project Partners.

6. Conclusions

Remote locations, land allocation, local authority approvals, and difficult installations are the main obstacles faced for the installation of microgrids in India. These challenges have been successfully resolved at the Keonjhar site. A 50 kWp microgrid has been installed, providing power to the local people. Work is still ongoing at the demo site to deploy fully the various ecoTools. The microgrid has significantly impacted the village, leading to the establishment of many small businesses. Additionally, the village, which previously relied on diesel engines consuming 6-7 liters of diesel per day per machine to power three rice-cum-hauler mills, has now transitioned to electric motors.