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Optimized Hybrid Renewable Energy System of Isolated Islands in Smart-Grid scenario-A Case Study in Indian Context

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***Abstract*—**This paper focuses on the integration of hybrid renewable energy resources available in remote isolated islands of Sundarban-24 Parganas-South of Eastern part of India to National Grid of conventional power supply to give a Smart-Grid scenario. Before grid-integration, feasibility of optimization of hybrid renewable energy system is monitored through an Intelligent Controller proposed to be installed at Moushuni Island of Sundarban. The objective is to ensure the reliability and efficiency of the system to optimize the utilization of the hybrid renewable energy sources and also a proposition of how theses isolated Hybrid Renewable Energy Systems at remote islands can be grid-connected is analyzed towards vision of green smart-grid.

***Keywords*—**Intelligent Controller, Hybrid Renewable, Solar Photo Voltaic, Smart-Grid

I. Introduction

SUNDARBAN is a vast area of low lying, inter-tidal tracts of Gangetic delta adjacent to the Bay of Bengal. In this paper, Moushuni Island of Sundarban-24 Parganas, South of West Bengal-Eastern part India, which is remote isolated island is electrified through hybrid renewable energy sources like solar photovoltaic(SPV) & wind with diesel back-up. It is proposed to optimize the hybrid power plants of these remote isolated islands of Sundarban with a proposition to grid integration in near future. But this proposition to connect the isolated remote hybrid renewable power plants to the conventional power grid is a challenge in the Indian scenario.

West Bengal Renewable Developments Agency (WBREDA) in Eastern part of India is trying to electrify remote isolated villages of this Sundarban isolated islands through hybrid renewable energies. The underlying issue for this grid-connectivity is that rural India will not get 40 % electricity to 50 % of time at the end of 13th plan. Hence, to make 24 hours reliable system for rural India, Hybrid Renewable Energy Systems must be optimized in the off-grid Smart Distribution System. Smart-Energy System is a Combination of Conventional & Renewable Energies. This paper focuses on integration of Hybrid Renewable Energy Systems of Solar, Wind, Bio-Mass to Feed Renewable to the National Grid to tackle power failure during peak demand utilizing Smart-Energy System by Energy Service Companies (ESCOs). This paper has analyzed with an objective to ensure the reliability and efficiency of the hybrid renewable system to optimize the utilization of the hybrid renewable energy sources at Moushuni Islands through Grid Interactive Operation of Solar Photo Voltaic (SPV) System at exiting operating plant at Moushuni Island of Sundarban-West Bengal-Eastern Part of India.

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II. Proposed Research in Case of Rural Electrification for Remote Isolated Islands of Sundarban-India

A. Proposition

The proposition to connect the isolated remote hybrid renewable power plants to the conventional power grid is a challenge in the Indian scenario. West Bengal Renewable Developments Agency (WBREDA) in Eastern part of India is trying to electrify remote isolated villages through hybrid renewable energies. As a part of National Solar Mission of India, decentralized hybrid renewable energy plants are already operating in isolated Moushuni Island of Sundarban of West Bengal-Eastern Part of India. Also decentralized Solar Energy for Village Electrification has been implemented in India. Grid extension for these isolated remote islands or villages can be the best option if the grid is reliable, the rural community rather big and in proximity to the grid.

III. The Criteria for Village Electrification of Isolated Islands of Sundarban

The criteria for village electrification are as: *(a)*Identification of parameters such as: *(i) Economic:* Cost of product, maintenance and operating cost, prevailing subsidy, tax benefits, benefit due to absence/lesser amount (than fossil-fuel-run equivalent system) of social/scarcity/opportunity cost, resale value, etc. – all in annualized quantities; *(ii) Social:* Energy habit of the customer, social custom, aesthetic value of the product, customers goodwill for reasons such as lowering of pollution by use of these “green systems”, political goodwill/propaganda, population density & accessibility of the location, grid connectivity, etc. and *(iii) Environmental:* Availability of solar radiation and other environmental conditions that would significantly affect the performance of the SPV system in consideration. *(b)* Quantification of each parameter should also take care of three levels of awareness of the target population, such as, Willingness for Power- A: Very Willing; B: Somewhat Undecided; C: Unwilling . Also considering parameters *(i) Totally un-aware; (ii) Aware but not yet totally realized;* and *(iii) Totally aware and realized. (c)* A reasonable time frame based on: *(i) Estimated product-life; (ii) The life of the technology;* and *(iii) Other factors* (viz. the dynamic nature of the above mentioned parameters, the replacement frequency that depends on general habit of the users etc.) Also considering Supply Time-A: 24 Hour Supply; B: Fixed Time Supply; C: Any Time Supply.

IV. Units

Grid extension can be the best option if the grid is reliable, the rural community rather big and in proximity to the grid. In many circumstances, a strong case for mini-grids based on hybrid systems can be made.

Scattered communities and isolated houses are well served by solar and small hydro (where available) or small wind energy systems.

V. OTHER ISLAND ELECTRIFICATION CASE STUDIES

A. Solar Home Systems Vs. Grid-Connectivity

Since rural electrification programs can easily over extend themselves, project appraisal needs to focus more attention on identifying the economic limits of extensions to the grid and on the economics potential of alternative energy sources, particularly solar energy (World Bank 1995 b).

Most electrical utilities examine only grid-based options when planning their rural electrification programs. PV projects should be appropriately integrated into the rural electrification planning process as a least cost electrification option 1. From the users' perspective, electricity from a reliable distributed grid is preferable, as long as it is affordable. From the country's perspective, national economic policy dictates a least-cost path to energy service delivery. The rural electricity planner needs to know how to select the least-cost approach to delivering energy services at an accepted level of reliability and quality from among off-grid options for power supply, including sola home systems, kerosene and batteries and a grid-based power supply.

B. The Economics of PV Household Electrification-A Case Study for Effect of Productive Loads on Break-Even Conditions-50Wp Solar Home Systems and a Diesel-Powered Isolated Grid in Indonesia

Indonesia, for example, the main sources of rural electricity are diesel engines serving isolated grids or large centralized generations that feed power to rural localities via medium – voltage transmission lines.

In Indonesia case study, three scenarios presented for villages located at varying distances from the existing grid, based on the assumptions, mentioned below: *(i) Case1:* A remote area where the grid option is to construct an isolated grid produced by a diesel or a small hydroelectric plant; *(ii) Case 2:* A village located 5 km from a medium voltage (MV) line; *(iii) Case 3:* A village located 3 km from a low voltage (LV) line (the typical maximum distance for LV line extension).

The break-even point at which grid-based power supply and PV systems are equally cost-effective in this assessment depends upon the size and density of the specific load to be served as well as the distance from LV and MV lines (See Fig. 1).

Assumptions: *(i) Level of Service:* (a) 8 hours area lighting; (b) 6 hours task lighting; (c) 60 Wh for other services; (ii) No Load Growth; (iii) 5 km distribution line per km^2 of grid service area(e.g. 100 households/km^2 = 20 households/km distribution line

For example, solar home systems are least-cost economic option for a remote vilage with no productive loads, 400 households, and a household density of 80 households/km^2.

However, an isolated grid would be the more economic option for the same village with 20 X 3 kW productive load sites for each 1, 000 households. Because, the cost of servicing productive loads with dedicated diesels (i.e., the solar home system alternative) exceeds the marginal cost of servicing the productive loads with the isolated grid, the economic niche for solar home systems is reduced. Therefore, if productive loads are likely for a particular village, they should be included in the electrification program.

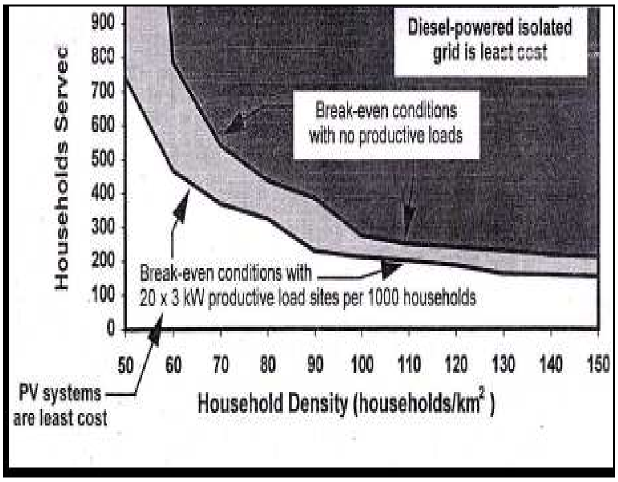

Fig 1. Effect of Productive Loads on Break-Even Conditions-50Wp Solar Home Systems and a Diesel-Powered Isolated Grid in Indonesia

C. The Development of Hybrid Integrated Renewable Energy System (Wind and Solar) for Sustainable Living at Perhentian Island, Malaysia

The energy efficiency and renewable energy under the Eight Malaysia Plan (2001 – 2005) and Ninth Malaysian Plan (2006 – 2010) focused on targeting for renewable energy to be significant contributor and for better utilization of energy resources. An emphasis to further reduce the dependency on petroleum provides for more effort to integrate alternative source of energy. Aware at the potential of the harvesting the wind energy, Malaysian Government under Joint venture partnership with the State Government of Terengganu and National Electric Board in 2007 embark on the project of integrating power supply at Pulau Perhentian (Perhentian Island). The project consists of installing two wind turbine, solar farm (Solar Panel), Generator and battery.

The main purpose of this project is to provide a reliable source for around the clock supply of electricity to the customer which is the people of Pulau Perhentian.

It is noted both wind turbine (WT 1 and WT 2) produce 18 KW each. Meanwhile the solar PV produce 39 KW. Total energy produce by RE farm is 75 KW. It was also noted that the site load requirement on that day is 71 KW. Therefore there is and access of 4 KW which will be stored in the battery. Therefore the energy produce by the two wind turbine will fulfill about 50 % of load required with the average wind speed of 7.26 m/s [6].

VI. Proposed Research in the most intelligent controller

To make Capacity Utilization Factor (CUF) better, optimization is required. For this optimization, the second phase off-grid Smart Distribution System, is the designing of most Intelligent Controller (Fig. 2). The Intelligent Controller will switch from various renewable resources like solar-wind-biomass through change over switch panel to find out optimized hybrid renewable energy system. The Intelligent Controller will extract the maximum energy input from the nature depending upon the seasonal change to feed to the distribution board to match between energy demand versus energy supply.

VII. Case analysis

A. Case Analysis of Moushuni SPV-Wind-Bio Hybrid Renewable Power Plant

WBREDA has set up a 53.5 kWp Solar PV Power Plant with an integrated daytime water supply system at village Bagdanga of Moushuni Island. Total population of this island is about 20,000. Primarily 300 families will be benefited with this Power Plant. Moushuni Island is a small picturesque island situated near Sagar Island and between Muriganga and Chinai rivers but very close to Bay of Bengal. *(A 20 kW Biomass Gasifier System is recommended to give back-up to this Hybrid Renewables System for a reliable electric supply during shortage of intermittent renewable like solar, wind)* [1-5]

Objective of the Project: Objective of the Project is (i) To Install Grid Interactive Operation of Hybrid Solar Photovoltaic (SPV), wind, bio-mass System at Moushuni Island;(ii) To ensure the reliability and efficiency of the system to optimize the utilization of the hybrid renewable energy sources; (iii) To design, fabricate and deply reliable power electronic fron-end interface with modular hardware; (iv)This modular hardware is made indigenously for converting power output from multiple small-scale renewable energy sources and storage elements into usuable voltage and frequency levels.

Problems: (i) The existing components in the existing system in Moushuni Islands for tapping sources like solar, biomass, wind etc. are not uniformly designed for integrated operation; (ii) Issues of maintenance, service and spares tend to reduce availibility of theses power plants.

Solutions: All interfaces need to be on a common AC link, which also serves as the feeder to the loads. A universal interface for hybrid renewable energy sources with technology for integrated operation is required.

*Technical Features :*These features are as follows (i) Maximum Power Point Tracking for wind electric generator(WEG) systems; (ii) MPPT for solar PV panels; (iii) Parallel operation of load side inverters; (iv) Parallel operation of battery chargers.

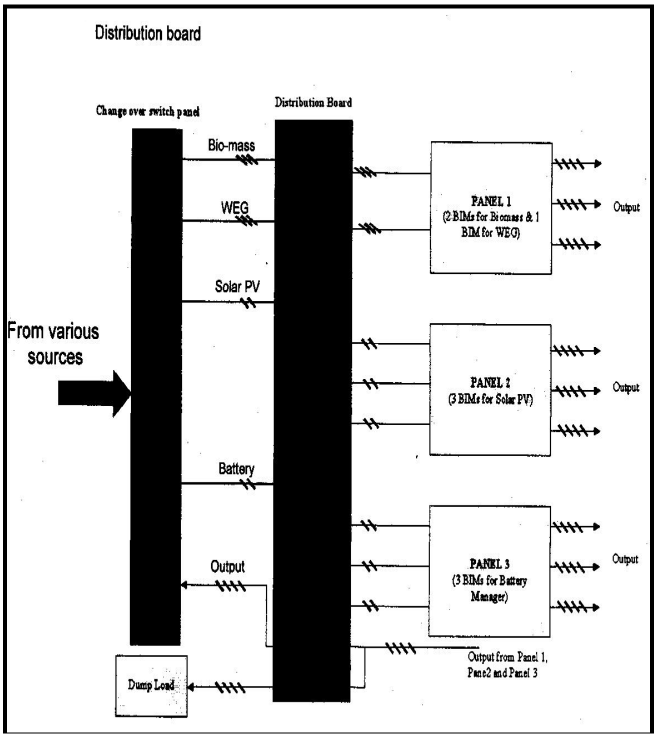

Fig. 2 Intelligent Controller for Optimized use of Hybrid Renewable Energy Resources Tested at WBREDA for Installing at Moushuni Island [1-5], [7]

Fig. 2 is illustration for the Assembled and Tested units proposed to be installed at Moushuni Island to control the solar-wind hybrid power plant for optimized use of renewable energy resources generated in the plant throughout the year to be grid-connected if required.

Input Side Features: The universal 10kW power electronic Basic Interface Module (BIM) with capability to interface with solar panels (variable current, DC), battery bank(fixed voltage, variable current, DC), wind generators (variable frequency, variable voltage AC), AC generator working from bio-mass(variable frequency, variable voltage AC) on the input side.

Output Side Features: The fixed frequency, fixed voltage AC link on the output side.

Control Algorithm: The control algorithm will ensure integrated operation of all the interface modules connected in parallel so as to feed a 20 kW load (Max.), to the feeder. Specific modules will be programmed with suitable control algorithms, which can be used to extract maximum power from a SPV source or WEG. A central controller is proposed to ensure the integrated operation of the power system and to realize user interface.

VIII. Conclusion

A universal interface for hybrid renewable energy sources with technology for integrated operation is required for the mini-grid integration of Sagar & Moushuni Islands of Sundarban to the nearest conventional eastern regional power grid.

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Thus sustainability can be achieved through extending mini-grids to the national unified grid through eastern regional grid. These hybrid renewables, of Sagar & Moushuni Islands of Sundarban after optimized utilization at isolated points, when integrated to national grid can face the power failure in peak demand period in national conventional grid. Ultimately integration of renewable energy systems to the national conventional grid can reduce CO2 emissions factors and is mitigating towards sustainable development. To overcome the barrier of the Grid-Connectivity of remote isolated islands of Sundarban of West Bengal-India as well to reduce cost/unit of production as well, a feed-in tariff (FIT) policy is encouraged. Also, multiple tariff system based on the exposure of a particular region to solar radiation should be adopted in India like Germany and USA instead of following a single FIT to set up solar power plants. This is a vision towards a green smart-Grid with integration of distributed hybrid renewables of isolated islands to national grid to have a sustainable future.

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