Possibilities to electrify a developing country considering local conditions

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***Abstract*—This work presents the creation of a sustainable electric power supply for an island grid. The grid is adapted to local and metereological data of Sundarbans region in India. Considering local data photovoltaics and hydro power prove to be the best fitting option for an eco-friendly supply. Both devices in combination with a battery storage system are designed in DIgSILENT *PowerFactory*. For the purpose of comparing two different scenarios the photovoltaic modules are placed once centrally and once decentrally. Based on load flow simulations, the loading of operating utilities as well as the voltage stability are evaluated in both settings. Both grid configurations provide security of supply and power system stability.**

***Index Terms*— battery storage system, island grid, power system planning, renewable energies**

I. Introduction

Due to their nearly unlimited local occurence renewable energy sources offer great potential to cover the electricity demand in remote areas. This work presents one possibility to implement a sustainable electric power supply for an island grid using the example of Sundarbans region in India. After evaluating local meteorological data an eco-friendly supply effectuated by photovoltaics and hydro power proves to be the best fitting option. Both devices in combination with a battery storage system are designed in order to guarantee uninterrupted energy supply. The island network is emulated in DIgSILENT PowerFactory. For the purpose of comparing two different scenarios concerning the integration of photovoltaics, the modules are placed once centrally and once decentrally. Based on load flow simulations, the loading of operating utilities as well as the voltage stability are evaluated in both settings.

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II. Procedure

A. Defining the energy sources

In order to define the kind of energy supply suitable for Sundarbans Islands, first of all, local meteorological data of *NASA* as well as information of the *Institute for Modeling Hydraulic and Environmental Systems* in Stuttgart are evaluated. With an eco-friendly solution in mind the local potential of wind power, biomass, photovoltaics and hydro power were analyzed.

The wind speed of Sundarbans Island does not exceed the limit of 5 m/s. Therefore, in Sundarbans Island, wind power is not reasonable considering economical and technical criteria [1]. Because of large protected areas as well as predominantly agriculturally used areas biomass turns out to be inadequate in the region of Sundarbans Island.

As an eco-friendly solution photovoltaics and hydro power prove to be the best fitting option. Whereas the photovoltaics offer a time-dependent power supply, the hydro power generates constant power supply because of nearly constant flow velocity. Both devices in combination with a battery storage system are designed in order to guarantee uninterrupted energy supply for 122 electrical consumers. The load consumes a total power of 15.25 kW between 4.00 am and 6.00 am and 18.00 pm and 0.00 pm [2].

B. Developing the island grid

The whole island network is emulated in *DIgSILENT PowerFactory*. For the purpose of comparing two different scenarios concerning the integration of photovoltaics, the modules are placed once centrally and once decentrally. The amount of photovoltaic modules and hydraulic turbines is empirically investigated requiring sustainability, security of supply, and economic efficiency.

Guarantee of security of supply

In consideration of the criteria sustainability, security of supply and economic efficiency the combination of 33 photovoltaic modules and six hydraulic turbines is determined for the central and the decentral scenario. This first dimensioning takes the lowest insolation occurring in August in order to provide security supply. A modified DPL-script of *DIgSILENT PowerFactory* is utilized to design the battery storage system which is adapted to the chosen generator combination. In this study the battery system requires a storage capacity of 101 kWh and a charging power of 12 kW.

Guarantee of economic efficiency

A subsequent study analyzes the correlation between the security of supply and economic efficiency. In order to do this, a second dimensioning uses the insolation values of the month April with the highest insolation values. A third dimensioning calculates with the hourly average values of all months. The result is a number of 22 photovoltaic modules and a storage capacity of 90 kWh for the April dimensioning. The dimensioning using average insolation values requires 29 photovoltaic modules and a storage capacity of 96.5 kWh. The number of six hydraulic turbines as well as the charging power of 12 kW can be retained unchanged for both dimensioning.

Results

To determine a blackout in a worst case scenario for the second and third dimensioning, the grid is in each case regarded in the month with the lowest insolation values, August. Furthermore, the maximum supply requirements are supposed. That yields a blackout of 9 minutes for the conception with the averages and 26 minutes for the conception with the values of April.

Comparing the cost savings of the April dimensioning with the August dimensioning, a decrease of 5% is obtained, due to the difference in the number of PV modules and battery size. In contrast to that, the average dimensioning only saves 2% of the acquisition costs. On the basis of these slight cost differentials, the chosen number of 33 PV modules assuming August insolation is economically absolutely justifiable regarding the year-round uninterrupted power supply.

C. *Load flow simulations*

To check the power systems stability and to draw a comparison between centrally and decentrally realized feeding of the photovoltaic modules, load flow simulations are performed in DIgSILENT PowerFactory. For this purpose the island grid containing the generator combination of 33 photovoltaic modules and six hydraulic turbines according to the August dimensioning is tested. In order to examine the loading of operating utilities under the circumstance of maximum insolation, the photovoltaic output curve of April is regarded. The evaluation considers the loading of operating utilities as well as the voltage stability of the grid.

With voltage deviations between +0.1% and -0.35%, the voltage stays within the prescribed bounds of +/- 10% all day. During the times of load both grid configurations show a slight decrease of their voltage. The only difference between the scenarios' voltage behaviors exists during the time of photovoltaic feeding when a small rise in the voltage curve of the decentral grid occurs. It emerges because of load flows from the low voltage grid towards the centrally placed battery storage system.

In the same way, the loading of operating utilities holds no risk for the power systems stability, reaching maximum values of 25% for the transformers and 10% for the transmission lines. Again, the influence of the photovoltaic feed can be seen in decentral grid. It creates an increase of the loading, but not its maximum which is due to the low share of photovoltaic in the electricity supply. Instead, this maximum is situated during the times of load and is identical in both scenarios.

III. Conclusion

Thus, a grid configuration was laid out supplying the consumer load of Bali Island in Sundarbans region adequately with regenerative energy. The approximately constant run of the grid voltage curve as well as the marginal loading prove the grids stability and permit its further extension. From a technical point of view, the decentral grid configuration harbors no drawbacks compared to the central one. However, contemplating economic efficiency, a centrally realized feeding could be favored, because there are no single distributed PV modules to be controlled. Besides, less inverters are needed due to the possibility of parallel operation of the PV modules. Both grid configurations provide security of supply, power system stability, and ecological sustainability.

References

[1] V. Quaschning, *Regenerative Energiesysteme.* München: Hanser, 2009, pp. 235–257.

[2] I. Mitra, "Optimum utilization of renewable energy for electrification of small islands in developing countries" Ph.D. dissertation, Univ., Kassel, in *Renewable Energies and Energie Efficiency*, 11th ed. Vol. 11, J.Schmid, Ed. Univ. Kassel, 2008, pp. 7-213.