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Modern Tools for Design, Feasibility and Performance Assessment of Hybrid Renewable Energy Systems

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***Abstract*— optimal design feasibility assessments of solar PV systems and hybrid energy based micro grids are having significant importance in the renewable energy sector. For design and feasibility analysis, simulation tools are given a significant importance. In this paper the design and feasibility assessment of the renewable systems using PVsyst and HOMER Pro software has been proposed. A 100 kWp, solar PV park has been modeled using PVsyst simulator, and its performance parameters are assessed based on the PVsyst simulations. HOMER Pro is a hybrid energy-based microgrid design software which is used for the design and feasibility analysis of hybrid energy-based microgrids and mini-grids. Hybrid energy based microgrid is designed and its feasibility analysis is performed. Based on the IEC-61724 standards, actual performance assessment is also presented.**

***Index Terms*— PVsyst, HOMER Pro, Performance ratio, CUF and Hybrid energy**

I. INTRODUCTION

Global environment concerns and the ever-growing energy demand have inspired researchers worldwide to focus on effective utilization of renewable energy systems. Solar PV and hybrid energy-based systems are considered to advance grid-connected and autonomous systems. In this perspective, the design of grid-connected and off-grid renewable energy systems are having significant importance. To protect the environment, it is necessary to reduce the power generation from conventional power plants and increase the clean energy production such as solar, wind, Biomass, fuels cells etc. The optimal design and development of an any renewable energy system it is necessary to use optimization tools. This tools are used for designing of a renewable energy system for high yields and economically feasible. Different tools are available for the design and analysis of solar PV and hybrid based systems such as PVsyst, PVgis, and HOMER. In this paper tools used for the designing of a solar PV and Hybrid energy based micro grids are elaborated with real-time examples “Ref.[1-5]”.

II. DESCRIPTION OF THE Pvsyst

PVsyst (Version no 6.85) simulation software is used for the design of Solar PV system, optimal sizing, and data analysis. Additionally. PVsyst is also used for designing grid-interactive solar PV systems, stand-alone solar PV systems, and solar water pumps. PVsyst makes use of physics behind solar photo voltaic technology, solar

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irradiance data based on meteorological data sources such as Meteonorm 7.2 and NASA-SSE and, the components of the PV system. Thus, PVsyst can help to understand the PV system components and thereby help to refine the system design. In PVsyst, solar PV systems can be designed in two stages. In stage one preliminary design can be done, and in stage two project design and simulation are carried out. PVsyst bases its monthly yield assessments on the fundamental system characteristics during the preliminary design phase. In project design and simulation, detailed hourly simulation occurs where users can perform different system simulations and compare them "Ref. [6-13]".

In the first step, after defining the plane orientation, a user is assisted in designing the PV array with the input parameters such as orientation of modules, inverter model and battery (optional for standalone solar PV system). In the second step, the user can specify technical specifications of the inverter, solar PV module, and battery bank to analyze the effects of thermal behavior, module quality, wiring mismatch, incidence angle loss and partial shading of near objects on the array. Fig. 1 shows the simulation process and block diagram of the PVsyst. To simulate the suggested grid-connected photovoltaic systems, the following actions are required (Venkatesh Boddapati et al., 2021).

1) Specify the location under consideration, such as longitude and latitude of the location for the solar PV system.
2) Import weather-related data (solar irradiance, wind speed, and ambient temperature) from the PVsyst database.
3) Define orientation of PV module (specifically tilt and azimuth angles).
4) Collection of solar PV structure components like PV components and inverter, based on system requirements.
5) Specify the user options for grid-interactive or independent systems.
6) Also specify the process to fine-tune the values for the kinds of losses.

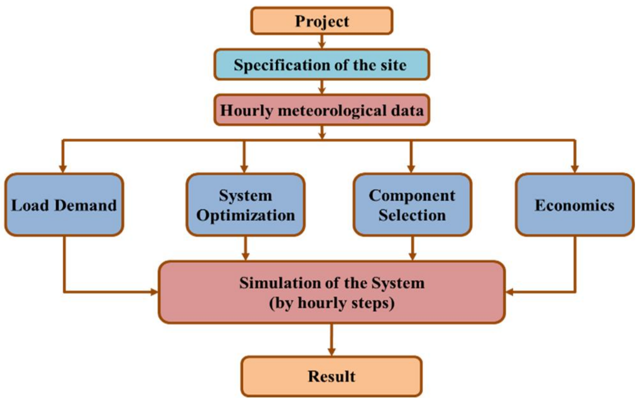

Fig.1 Block Diagram of PVsyst Simulator

III. HOMER PRO FOR HYBRID ENERGY SYSTEMS DESIGN

HOMER is a microgrid modeling and analysis software, established by NREL (National Renewable Energy Laboratory). It is used for modeling the microgrid based on load requirement and to evaluate the various power generation technologies. The design and analysis of a microgrid by using HOMER is very motivating and challenging due to many design choices and the ambiguity significant parameters, such as variation of load with respect to time, upcoming fuel price variations, inflation effect on the project, and the consequence of deduction rates on the microgrid projects. Incorporating renewable energy in a microgrid enhances the system complexity, as the output power depends on location and climatic conditions. HOMER performs simulation in three different stages and analyzes the design of the system with respect to cost and sensitivity. Fig. 2 shows the relation between simulation, optimization, and sensitivity analysis.(Lambert et al., 2006)

Based on the energy stability estimate for each year's period step, HOMER runs the simulation. In each step, HOMER relates the electrical and thermal energy requirements with the energy the system can source in the step and computes the flow of energy from each source of the system. The system comprises of storage devices and a fuel power generator. HOMER makes the decisions about running fuel-based generators and charging or discharging the batteries. HOMER performs simulation for each configuration and then determines the configuration feasibility with respect to the electrical load requirement. The software also estimates NPC, LCOE, capital cost, operating cost, and maintenance cost.

HOMER has two optimization algorithms which are search space and HOMER optimizer.The unique grid search process simulates all the practical system alignments clear in the search space. (The user gives exploration space boundary). After searching for the system's lowest cost using this exclusive derivative approach, HOMER displays a list of structures arranged according to net present cost, which is used to calculate the scheme design cost.

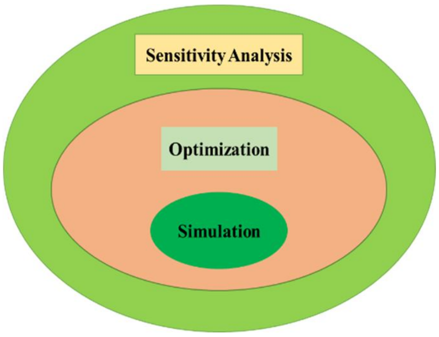

Fig.2 Relationship between simulation, optimization, and sensitivity analysis

A. Sensitivity Analysis

Uncertainty in important variables is a problem that microgrid designers commonly face. Sensitivity analysis helps the designer understand how an uncertain variable affects the project and assists them make wise design choices even during uncertainty. In the sensitivity study, the user enters the different sensitivity parameters as input. For example, variation in fuel cost, variation in inflation rates, and variation in discount rates, price of grid power, and solar system lifetime. Variation of renewable resources is also considered as another sensitivity variable. HOMER performs the simulation for each variable and shows the effect of each variable on the project. For example, if the user identifies three fuel cost variations and four values as interest rate that indicates 12 different sensitive cases, then HOMER performs the simulations for individual sensitive case and produces the results in tabular form and graphical form

B. Modelling of Proposed System Architecture using Homer

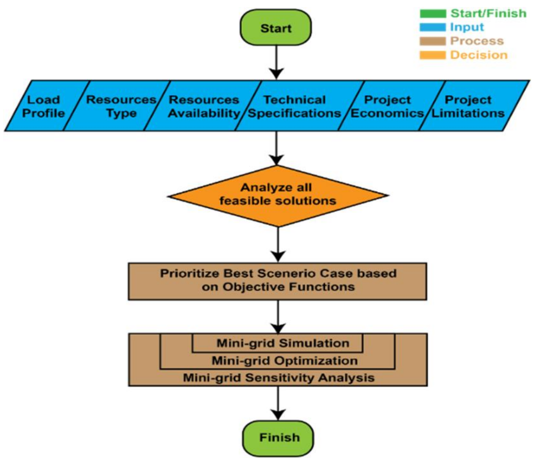

Fig.3 Flowchart to derive the optimum structure using HOMER software.

Availability in the position, technical conditions of each constituent, project finances, and project limits. HOMER optimization procedure is used to select the best configuration from among the various designs and perform project techno-economic performance assessment. The sensitivity examination is a single simulation setting in HOMER that predicts the future of microgrid projects for unpredicted environments.

IV Results

A. Case Study-1 PVsyst

a. Solar PV System Performance

Calculation of performance limits is used to govern the feasibility of the fitting of the solar PV system. The performance indices of the roof-top solar PV system are made based on PVsyst simulations. Fig 4-6 represents the predicted energy output, forecasted PR, and forecasted CUF, respectively. Figure 4 demonstrates the variation of energy output in various months of a year. The maximum energy generated with tracking system in January is 16.880 MWh, and the lowest energy generated in July is 10.850 MWh. The power produced from the solar PV system depends on several factors, such as array temperature, ambient temperature, solar irradiance, and wind variation in the site. Technical specifications of solar PV module and string inverter are given as follows.

Fig.4. Solar PV system energy output

b. Performance Ratio (PR)

It is the ratio of last yields to the reference yields. It signifies the general impact of losses on solar PV arrays. This issue is used to regulate if the system is working as estimated. Higher PR determines the effectiveness of plant process. Figure 4 validates the performance ratio of the simulated solar PV system. The highest PR using tracking system is experimental in June, July and November, and the lowest PR is observed in April and May. PR is a system-dependent amount and does not gets pretentious by solar irradiance.

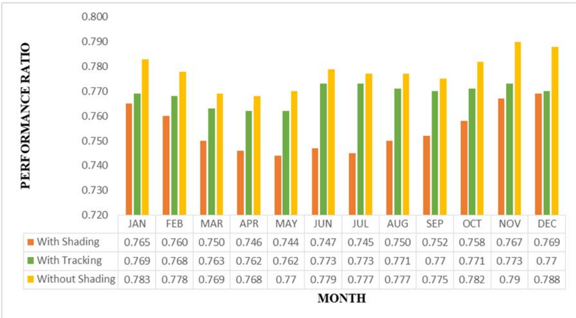

Fig.5 PR of the solar PV system

c. Capacity Utilization Factor (CUF)

It is the ratio of actual generated energy to the theoretically possible maximum energy from the PV system for 24 hours for a period of one month. It represents the energy delivered by a power generation plant. If the solar PV system delivers rated power continuously, the capacity utilization factor would be unity. Factors that affect the CUF are solar irradiance and the number of clear sunny days experienced by the installed solar PV array. Figure 5 demonstrates the capacity utilization factor of the solar PV system.

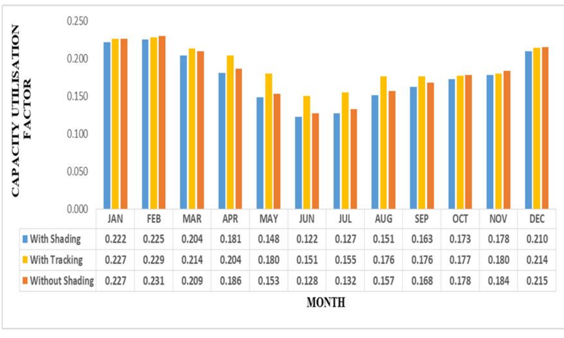

Fig 6. CUF of solar PV system

The highest CUF observed using Tracking system in February is the result of high irradiance and more clearly sunny days in the prevailing summer season, and the lowest CUF is observed in June and July is the result of low irradiance and less clear sunny days due to monsoon season.

$$\text{CUF} = \frac{G_M}{(\text{Pi} * \text{number of days in a month} \times 24)}$$

B. Case Study-2 HOMER Pro

Homer Pro is a micro grid design software it is used to design hybrid energy based microgrid. Fig.7 shows the proposed microgrid simulated using Homer pro software. It consists of various renewable energy sources such as solar, wind and Biomass. Optimization is performed using HOMER pro and the results are presented in Fig. 8 to Fig.13.

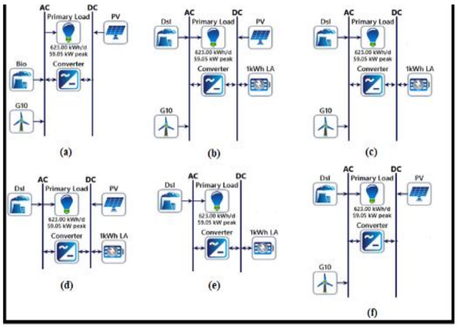

Fig.7 Proposed micro grid system with various sources

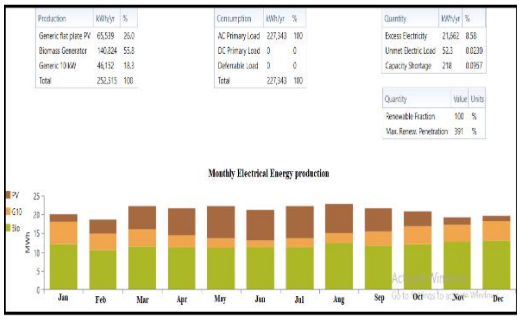

Fig.8 Monthly electrical energy production from various sources

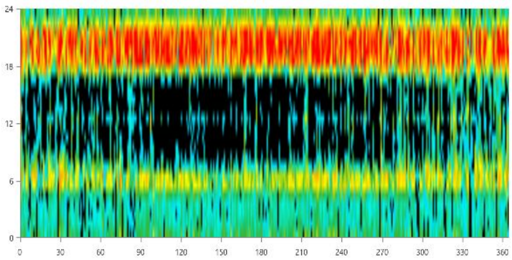

Fig.9 Biomass Generator Output (kW)

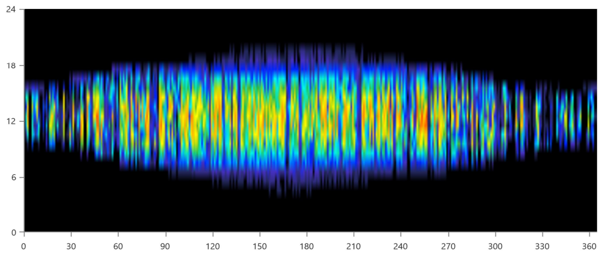

Fig.10 Generic flat plate PV Output (kW)

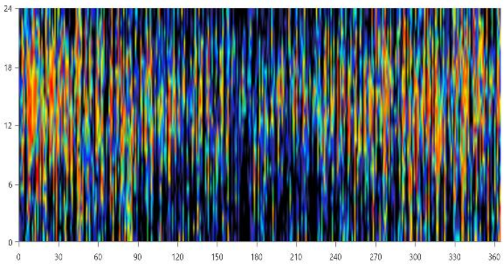

Fig.11 Generic 10 kW Output (kW)

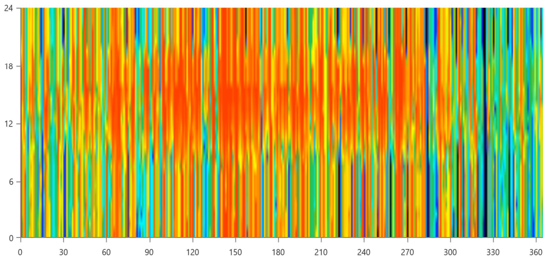

Fig.12 Generic 1kWh Lead Acid State of Charge (%)

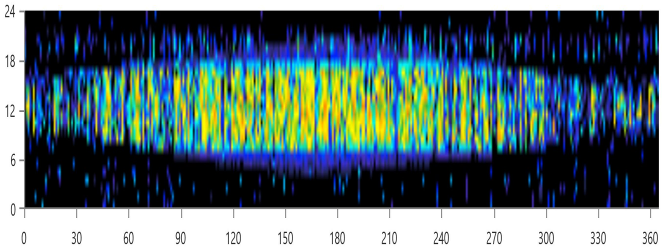

Fig.13 System Converter Inverter Output (kW)

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