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# Techno economic study of Hybrid Renewable Energy System (HRES)

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***Abstract:***

This paper shows the techno economic study of grid connected Hybrid Renewable Energy System (HRES) for remote area Surajpura (latitude 23° 50' 20.5944" N, longitude 79° 26' 27.6900" E) small village in Jabera Tehsil in Damoh district of Madhya Pradesh, India. The techno economic analysis of proposed HRES is done by HOMER Pro Software. The author has suggested the use of renewable energy to overcome this problem. HRES has been proposed for the remote area Surajpura which consists of solar-wind-biogas-DG and battery connected with grid. HOMER Pro software is used to solve sizing and optimization problems. The optimization result gives the different combinations of HRES. Hence the system determines optimal configurations with minimum value of NPC and COE. Optimized system has economic feasibility, beneficial for environment, payback period and less emission.

## I.INTRODUCTION

In many regions, despite extensive availability of renewable-based electricity generation options, the advantage cannot be taken due to either unavailability or limited capacity of the transmission and distribution grids. Installation of additional lines and grid reinforcement methods for increasing the capacity are costlier options which take several years to complete (Shahzad, M.; Qadir, A.;Ullah, N.; Mahmood, Z.; Saad, N.M.;Ali, S.S.A 2022)

Therefore, on-site generation i.e., generation near the demand centers to avoid the need of transmission networks is considered to be the most viable solution under such conditions. On-site generation also helps in reducing the transmission losses, network congestion, and capital investment requirements. However, such benefits can be fully exhausted if the optimally sized renewable-based generation is optimally placed within the grid (Shahzad, M.; Gawlik, W.; Palensky, P(2016).

In India, rural community uses fossil fuel and wood for their domestic power demand. Using these energy sources leads to climate changes, environmental changes, and health-related problems. Thus, the renewable energy resources interest is increased due to environmental friendliness, availability, and low running cost (Østergaardet al. 2020; Gürel et al. 2020)

The interest in renewable energy sources (RES) based DGs has increased due to their smaller footprint, quicker installation, and environmental impacts.. However, it is noteworthy that due to unplanned and non-optimal placement of such generation resources, the power network and power system face challenges such as, but not limited to, power quality, power congestion over the network, and reverse power flow (Shahzad, M.; Akram,W.; Arif, M.; Khan, U.; Ullah, B 2021).

Moreover, the energy harvesting can be maximized if the RES-based DGs are installed after studying the availability of primary energy, power requirements, land availability, and cost of the DG systems and the cost incur on connecting these generators to the main grid. It is, therefore, necessary to optimize the planning of DG installation based upon these factors. This work focuses upon mitigating the problem of power shortage by proposing an on-grid Hybrid Renewable Energy System (HRES). The hybrid system is preferred to minimize the challenges posed due to intermittent nature of most renewable resources (Khan, I.A.; Khan, M.R.; Baig, M.H.A.; Hussain, Z.; Hameed, N.; Khan, J.A.(2020)

**Details of Research Area**

As we know that the electricity is not available 24 hrs in rural areas of India. So the motive of the research is to provide 24hrs electricity to rural area at minimum cost. So the as the article published in Time of India Surajpura small village/hamlet of Jabera tehsil in Damoh district of Madhya Pradesh, India. It is 40 km towards east from district head quarter Damoh. Village/locality is facing problem like electricity outage, water supply shortage, rationing of food grains issues etc. Only 10 hours agricultural electricity supply is available in summer and winter season. Total population is 550 and number of houses are 110. Female Population is 48.2%. Village literacy rate is 45.8% and the female literacy rate is 19.3%. Total area is 138.35 hectares, Non-agricultural area is 11.67 hectares and total irrigated area is 97.4 hectares. Rice, Wheat and Gram are main agriculture crops grow in this village [www.onefivenine.com]

Other problems that are pinching the people are unemployment. Figure 1(a) and (a) shows the location of the study area and its google map position respectively.

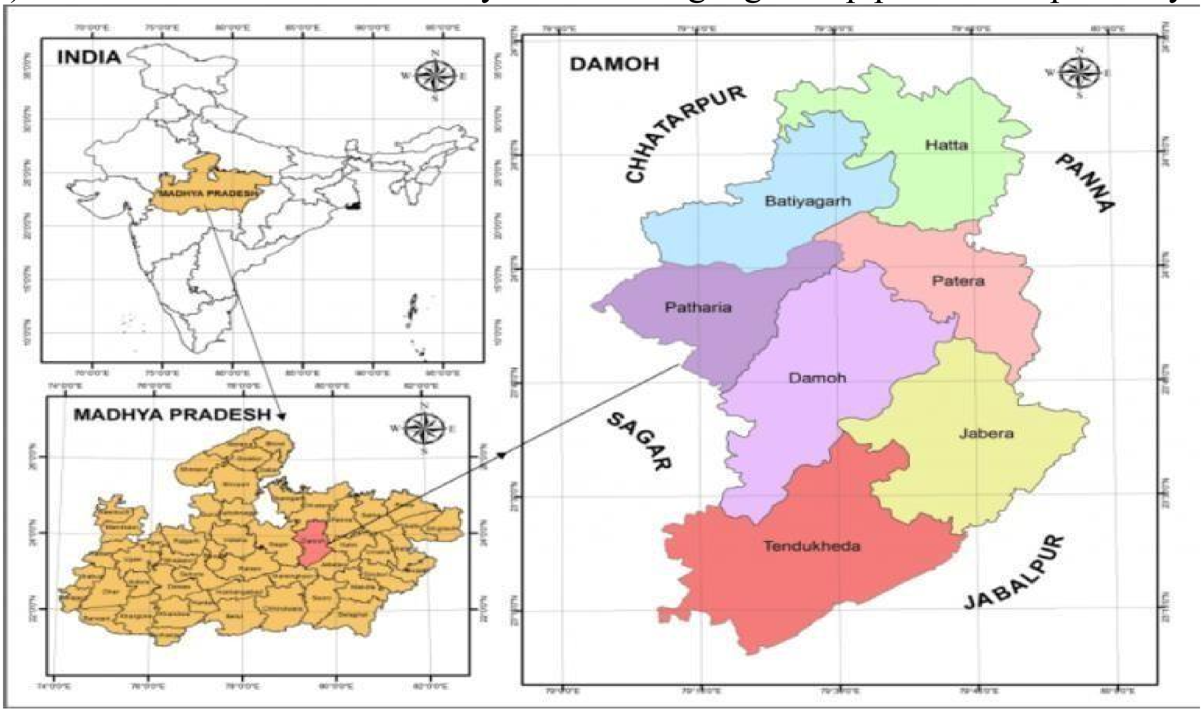


Fig1(a) Location of tehsil Jabera of Damoh district of MP,India

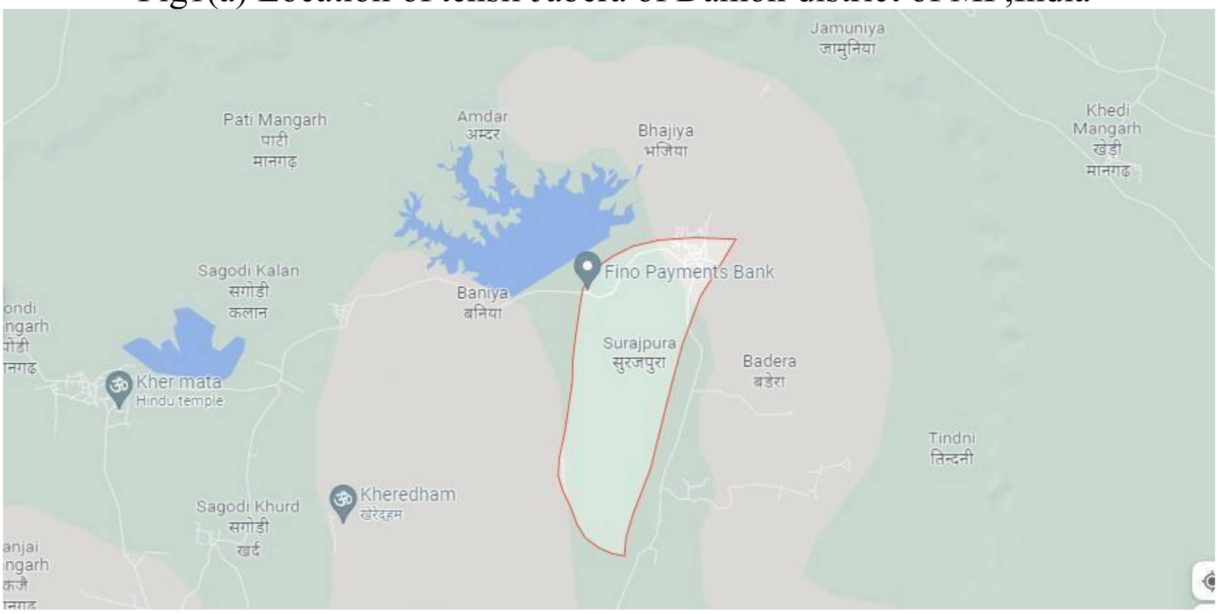


Fig 1(b) Location of Surajpura village on google map [www.onefivenine.com]

## Proposed HRES Configuration

1. From the available literature it has been observed that research can done to devlop various configurations of HRES models. After going through literature and understanding the location and terrain of the study area, a Hybrid model is proposed for modeling and optimization of an off-grid HRES for energy needs of the area. The Hybrid model has a combination solar-wind-biomass with battery. The optimization and sizing problem is solved by HOMER Pro software.

Performance of the system is evaluated and compared by different combinations of HRES. Optimized system with minimum value of NPC and COE and reasonable environmental benefits, attractive payback period and also fewer emissions. Sensitivity analysis is also shown for variation in annual wind speed and biomass fuel prices, with cost of energy and net present cost. [http://analysis.nrel.gov/homer]

# II. METHODOLOGY

**Energy Demand assessment**

The methodology is based on the energy demand estimation of the study area for simulation and optimization. The demand is classified in different type like domestic, commercial, industrial, community and agricultural load demands. Domestic and community load demand come under minimum load, while the others are considered as desirable demands.[ H. C. de. Coninck, K. J. Dinesh July 2005]

In minimum load the household electricity demand can be evaluated as per the villager's requirements or it can be estimated an average value in other villages and calculated for existing population. Community demand should be calculated on the basis of lighting load for school in the village for community activities in the evening, Point for community TV, Load for primary health centers (PHC), Panchayat Bhavan/community hall, streetlights and pump for drinking water supply.

The desirable demand consist of commercial demand should be assessed on the basis of income generating activities. Total energy requirement should be calculated on the basis of minimum and desirable load profile. Total minimum load of the village consist of minimum domestic load plus community load while total desirable load consists total desirable domestic load, community load, commercial load, industrial load and agricultural load. [M. G. Green 2002]

**Resource assessment**

The resources assessment play important role for selection of HRES configuration for electricity generation. For assessment the primary information should be collected from the field and secondary data should be available from different sources. The renewable energy resources may be solar, biomass, small hydro, wind and sources of biogas. Suggested thresholds for different resources for determining feasibility are given in Table 1 [M. G. Green 2002]

Table 1 Amount of a site resource typically needed for feasibility [M. G. Green 2002]

| S No | Resource | Needed for duration |
|---|---|---|
| 1 | Full sunlight (hrs/day) | 2 hr/day or more |

| | | |
|---|---|---|
| 2 | Wind speed (m/s) | 4 m/s or more |
| 3 | Stream speed (m/s) | 1 m/s or more |
| 4 | Biomass | Depend upon no. of cattle (24 kg ≈ 1 kWh) |
| 5 | Fuel cost (Rs/liter) | Depends upon application |

**Energy demand statistics for proposed Area**

Cost effective modeling of the HRES supplying the energy needs of the proposed study area is trying to achieve. The village is considered to be located in remote area with sufficient sunshine, low to moderate wind speeds (varies from 2.99 m/s to 6.37 m/s), and biomass resource is available in sufficient amount..

The proposed area is considered to have total renewable energy potential of about 308,778kWh/yr including all the renewable energy resources (Solar, Biomass and Wind). Total estimated demand is about 208,254 kWh/yr (as shown in Table 2). This means that the energy demand of the area can be fully exploiting the available resources.

Table 2. Energy sources, and energy demand statistic of the proposed study area [www.onefivenine.com]

| | **Statistics** |
|---|---|
| **Demography** | Households -110,<br>People – 550<br>Cattle - 250 |
| **Energy sources** | A. Biomass: 291,539 kWh/yr<br>B. Solar: 10,249 kWh/yr<br>C. Wind: 6,990 kWh/yr<br>Total Potential: 308,778 kWh/yr |
| **Energy Demand** | A. Lighting load: 133,824 kWh/yr<br>B. Cooking load: 18,759 kWh/yr<br>C. Agriculture load: 62 kWh/yr<br>D. Motive/Industries load: 12,181 kWh/yr Other Domestic load-<br>1. T.V. load: 23,736 kWh/yr |

| | |
|---|---|
| | 2. Fans load: 19,692 kWh/yr<br>Total Load: 208,254 kWh/yr |

**HRES configuration and inputs provided**

The proposed HRES Configuration is shown in figure 2 consists of solar PV system, Wind Turbine, Biomass Generator, converter and Electric load connected to grid. They are connected on AC and DC bus depending on the output of the generator. Converter converts the DC output in to AC to be utilized by load.

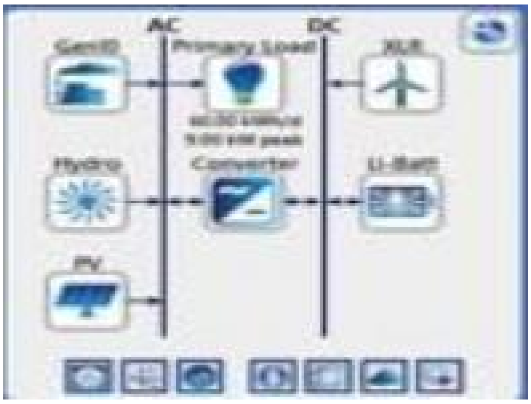


Figure 2 The arrangement of hybrid power system

## Load profile

The daily and seasonal load profile of the area is shown in figure 3. In daily load profile it showed the variation of load during a day i.e. 24hours. The peak load in daily and seasonal profile is observed in the month of November and between 6 to 8pm.

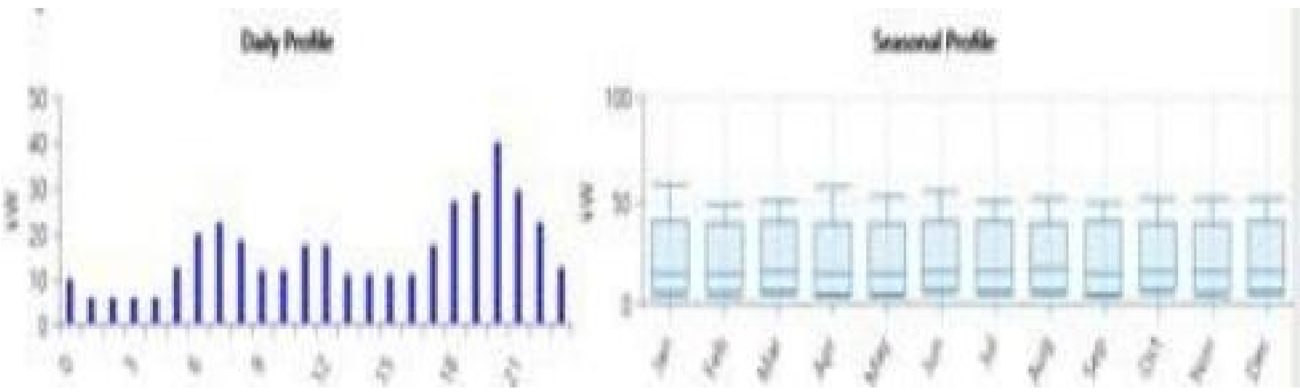


Figure 3 Load Profile

The global solar monthly average is shown in figure 4. The maximum global solar radiation is in month of April and minimum is in month august.


Figure 4 Global Solar Monthly Average

Solar time series detail analysis. Fig 5 shows the global solar daily profile in which during noon time between 11:00am to 1:00pm the radiation are maximum (0.80KW/m$^2$).

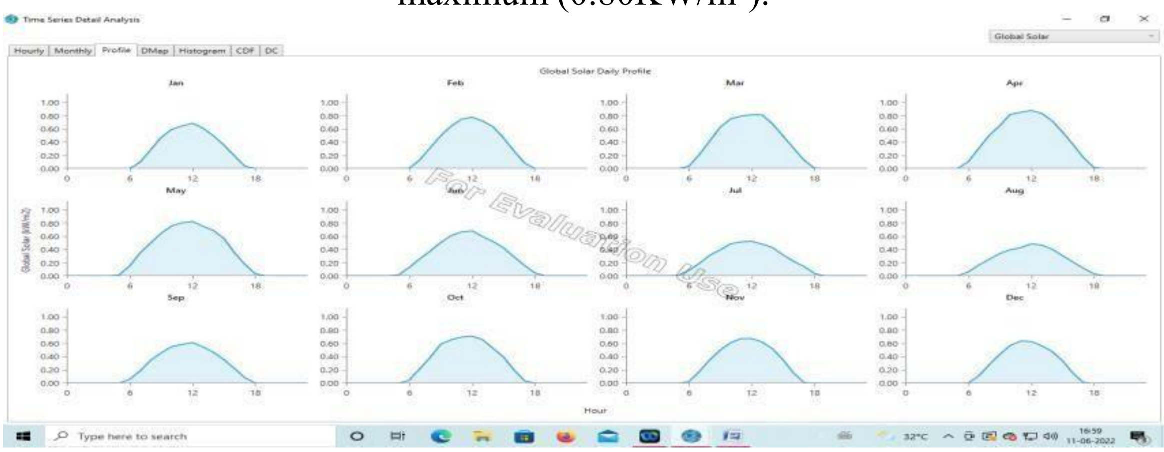


Figure 5 Solar time series detail analysis

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# III. RESULT AND ANALYSIS

The result of proposed HRES configuararion is shown below. Figure 9 shows the screenshot of simulation result of suggested HRES (PV/Generator/Wind). This simulation is based net present cost in categories by component wise.

Figure 6 show the different configuration of Hybrid Renewable Energy System.

Select Base Case

Choose a base case to compare with other systems for economic analysis. More detailed economic comparison is available in Simulation Results.

Categorized Overall

| Architecture | | | | | | Cost | | | | System | | Dsl | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PV (kW) | XLR | Dsl (kW) | Li-Batt | Hydro (kW) | Converter (kW) | NPC ($) | COE ($) | Operating cost ($/yr) | Initial capital ($) | Ren Frac (%) | Total Fuel (L/yr) | Hours | Production (kWh) | Fuel (L) | O&M Cost ($/yr) | Fuel Cc ($/yr) |
| 3.73 | | 10.0 | 16 | | 4.00 | $104,695 | $0.370 | $5,583 | $32,519 | 16.1 | 7,020 | 3,035 | 18,367 | 7,020 | 607 | 2,808 |
| | | 10.0 | 22 | | 4.00 | $112,765 | $0.398 | $7,129 | $20,600 | 0 | 8,948 | 3,697 | 23,962 | 8,948 | 739 | 3,579 |
| 2.21 | 1 | 10.0 | 16 | | 4.00 | $125,483 | $0.443 | $5,419 | $55,433 | 29.4 | 5,963 | 2,623 | 15,459 | 5,963 | 525 | 2,385 |
| | 1 | 10.0 | 10 | | 8.00 | $127,790 | $0.451 | $6,234 | $47,200 | 14.5 | 6,477 | 2,243 | 18,729 | 6,477 | 449 | 2,591 |
| | | 10.0 | | | | $148,565 | $0.525 | $11,028 | $6,000 | 0 | 14,392 | 8,760 | 29,536 | 14,392 | 1,752 | 5,757 |
| 0.00651 | | 10.0 | | | | $148,590 | $0.525 | $11,028 | $6,026 | 0 | 14,392 | 8,760 | 29,535 | 14,392 | 1,752 | 5,757 |
| 3.53 | | 10.0 | 16 | 16.6 | 4.00 | $166,157 | $0.587 | $6,531 | $81,726 | 15.1 | 7,107 | 3,074 | 18,592 | 7,107 | 615 | 2,843 |
| | | 10.0 | 22 | 16.6 | 4.00 | $174,096 | $0.615 | $8,006 | $70,600 | 0 | 8,948 | 3,697 | 23,962 | 8,948 | 739 | 3,579 |
| 5.00 | 1 | 10.0 | | | 2.00 | $184,645 | $0.652 | $9,889 | $56,800 | 0 | 11,943 | 7,332 | 24,309 | 11,943 | 1,466 | 4,777 |
| | 1 | 10.0 | | | 2.00 | $185,173 | $0.654 | $11,477 | $36,800 | 0 | 13,998 | 8,631 | 28,374 | 13,998 | 1,726 | 5,599 |
| 2.21 | 1 | 10.0 | 16 | 16.6 | 4.00 | $186,814 | $0.660 | $6,295 | $105,433 | 29.4 | 5,963 | 2,623 | 15,459 | 5,963 | 525 | 2,385 |
| | 1 | 10.0 | 10 | 16.6 | 8.00 | $189,120 | $0.668 | $7,110 | $97,200 | 14.5 | 6,477 | 2,243 | 18,729 | 6,477 | 449 | 2,591 |
| | | 10.0 | | 16.6 | | $209,895 | $0.741 | $11,904 | $56,000 | 0 | 14,392 | 8,760 | 29,536 | 14,392 | 1,752 | 5,757 |
| 0.00651 | | 10.0 | | 16.6 | | $209,921 | $0.741 | $11,904 | $56,026 | 0 | 14,392 | 8,760 | 29,535 | 14,392 | 1,752 | 5,757 |
| 5.00 | 1 | 10.0 | | 16.6 | 2.00 | $245,976 | $0.869 | $10,766 | $106,800 | 0 | 11,943 | 7,332 | 24,309 | 11,943 | 1,466 | 4,777 |
| | 1 | 10.0 | | 16.6 | 2.00 | $246,503 | $0.871 | $12,354 | $86,800 | 0 | 13,998 | 8,631 | 28,374 | 13,998 | 1,726 | 5,599 |

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Figure. 6 Optimization of different configurations of off grid hybrid power system

Figure 7 show the graphical representation of different combination of stand alone hybrid power system (Diesel/Hydro, Diesel/Hydro/Lithum Battery, Diesel/PV/Lithium Battery, Diesel/PV/Lithium Battery/XLR, Diesel/Lithium Battery/XLR, Hydro)

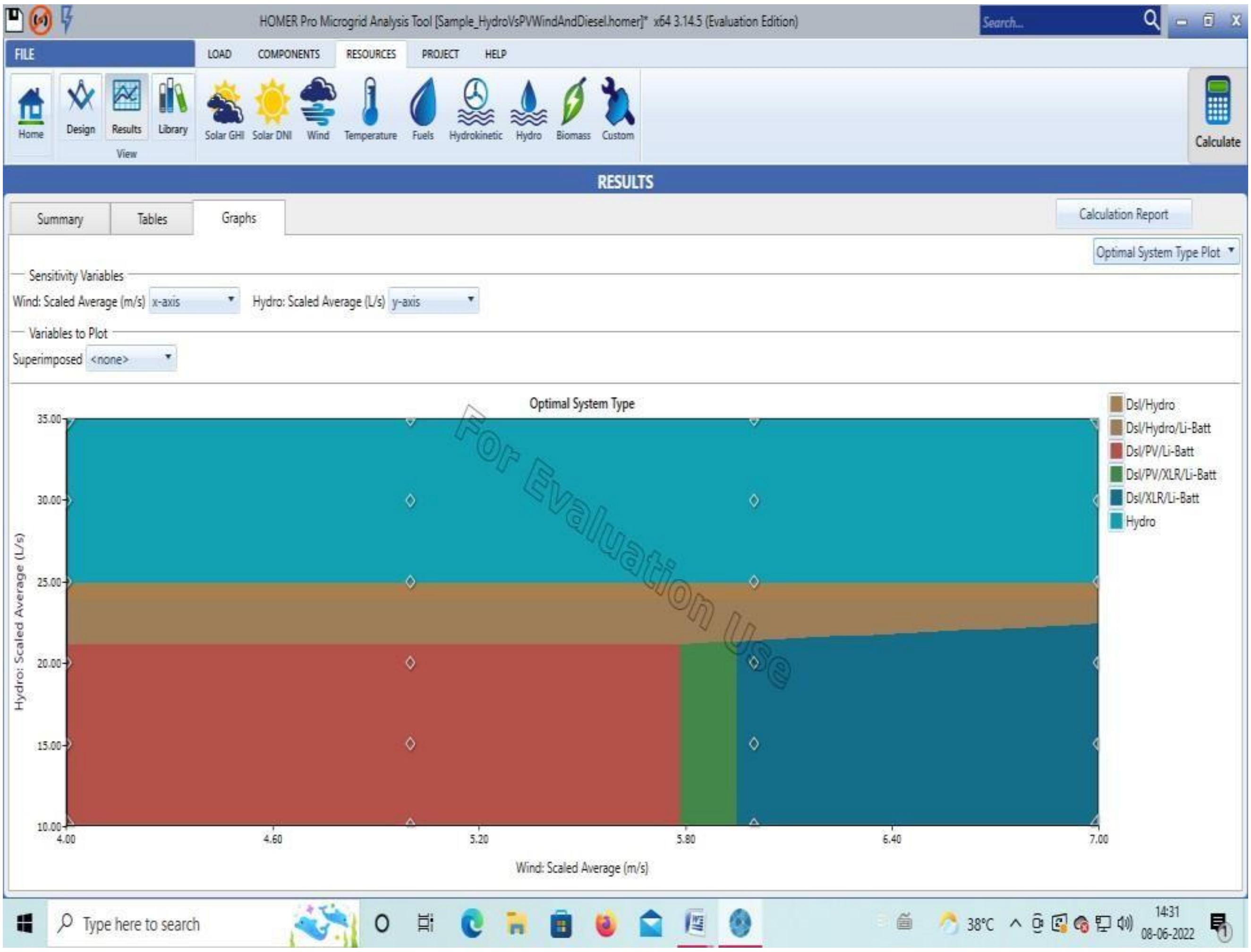


Figure. 7 Graphical representation of different combination of standalone hybrid power system

Figure 8 shows optimized result of proposed stand alone connected hybrid power system. In the result it show Net present cost, Intital cost, Operational and Maintance cost, Low cost of Energy, Pay back period etc)

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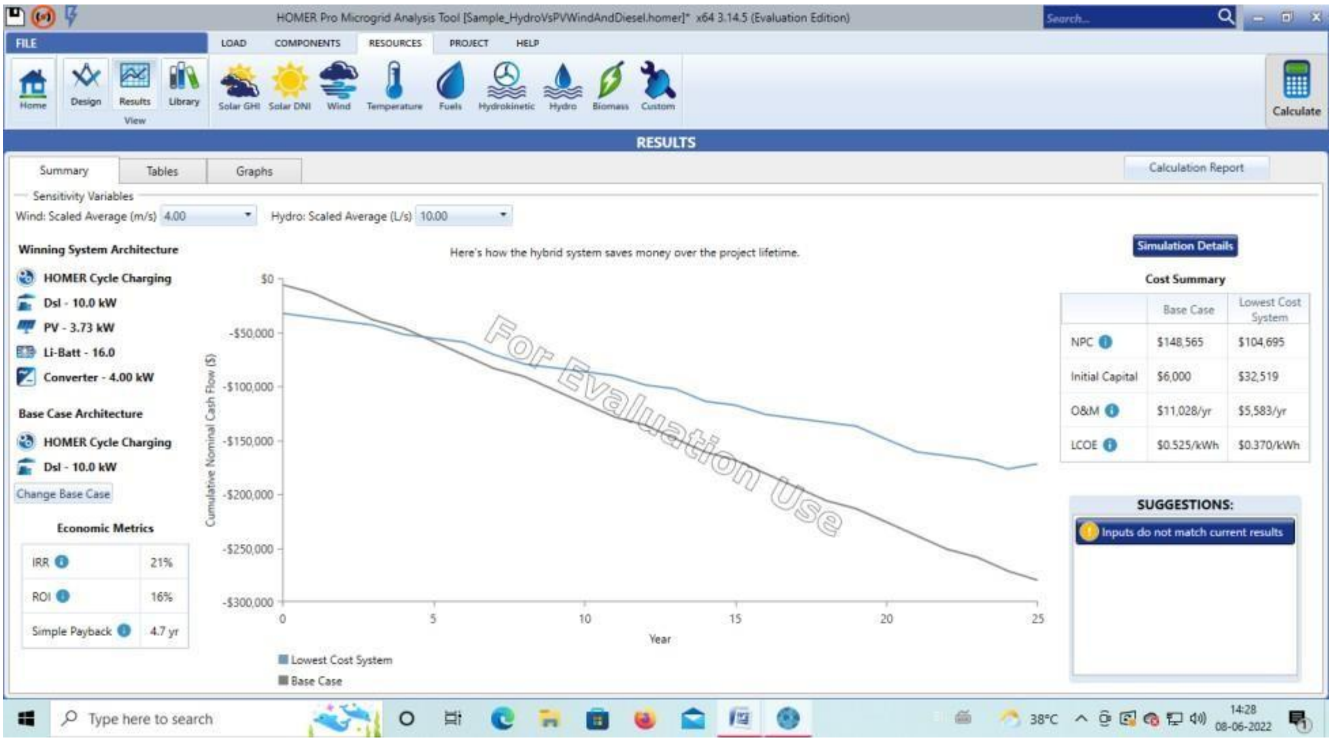


Figure. 8 Optimized result of proposed stand alone connected hybrid power system

# III.CONCLUSION

This research has been done to realize a useful and rich technology that can be linked to meet the needs of consumers by saving electricity. This process is a combination of PV, DG, Hydro and Battery Stand alone hybrid system. This study was conducted to study Surajpura, Damoh district in Madhya Pradesh India to develop the concept of the use of electric power supply. For the equivalent load of kWh/day and the maximum load of 9.67 kWh, the cost of electricity (COE) for the consumption of the external power source is 0.1920$. The implementation of the proposed grid hybrid system reduces gas emissions in significant quantities due to lower fuel consumption. The carbon dioxide emission rate in this study was 138,589 kg per year and the sulfur dioxide emission rate was 601 kg per year. The major analysis of the proposed system is that in the months of April to august the hybrid system will sold the energy to the grid

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