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SIMULATION OF HYBRID RENEWABLE SYSTEMS IN RURAL AREAS

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Abstract
Renewable Energy (RE) sources are being used nowadays to overcome grid instability. A different hybrid model is used to balance energy production, reducing excess energy where PV (Photovoltaic) production is highly stochastic due to fluctuations in irradiance and temperature. The main problem of renewable energy sources is uncertainty. The velocity is also not stable according to the location in terms of wind energy. A technical and financial plan can mitigate the maintenance cost in a hybrid system. A hybrid renewable energy system is a combination of different energy sources. The sources are considered a combination of complete renewable or renewable and other conventional energy sources such as diesel generators, utility grids, etc. In the research, the technical and financial plan can be implemented in sustainable management after installing the hybrid system; monitoring the production is also a big problem nowadays. The research method is general, and the test scenario has been based in Mozambique. A predictive model can maintain a consistent power flow of renewable sources such as photovoltaic, wind, utility grid, and inverter systems. The renewable sources data are variant according to their location, and it has an impact in terms of energy production. In a modern sustainable framework, considerable data control is required for administration, miniature networks, and environmentally friendly power supplies. The target of this research is to introduce simple technical planning for the community living in a rural area and for the local electricity provider or the consultants to plan a hybrid system in areas and collect the data and understand simple data analysis techniques so that the future production, storage capacity, excess energy can be identified. The research is a theoretical plan before the practical installation of a hybrid system. It is important to have a proper plan before the establishment of such a system otherwise the inappropriate plan causes extra costs and loss of energy which is not an idea criterion to implement renewable energy-based hybrid systems. We will discuss the importance of data collection from the hybrid system and later analyze the data to observe the energy production, excess energy, annual energy cost, maintenance cost, etc. Data visualization is important to monitor the correlation between all necessary parameters of the design which can assure better stability of a system. Data analysis is also an important part nowadays because of forecasting or predicting the future outcome of the system. This theoretical approach can be implemented after practical installation on-site and the technical plan, visualization, data analysis methods can be used also for the project.

Key Words: Utility Grid, Big Data Analytics, Hybrid-System, Renewable Energy, ROI, IRR, NPC, NPV, Excess Energy, Output Energy.

Introduction
Awareness about renewable energy has been rising in the last ten years. Renewable energy sources have shown tremendous worth in the energy business over the last decade. More and more nations are turning to renewable energy, with the renewable industry estimated to reach $2.15 trillion by 2025 [9]. Energy suppliers are finding it challenging to seek better ways to manage the expanding energy infrastructure in the face of continuously increasing demand. While renewable energy sources can fulfill market demand and provide continuous energy, their inconsistency complicates infrastructure operations and challenges utility companies and customers. California wind and electricity facilities can create more than needed energy during the summer months compared to underperforming winters [10]. The energy sector increases intelligent grid technology, stabilizing the supply of green energy and future-proofing renewable as stable and only energy resource. A technical guide can be helpful for innovative grid management: asset management and joint operations, demand-side management, power generation side management, for hybrid renewable energy management. The research discusses the platform in terms of technology to integrate renewable energy sources, which need a systematic framework for installation, managing, analyzing, monitoring, and forecasting massive data coming from the system. In recent years, the energy sector has experienced a fast development of solar generating technology, increasing involvement in the local grid. The data is collected from the simulated hybrid system. The research aims to find a feasible solution for the mentioned area, which can also be utilized in different rural areas. A different hybrid model will be presented here in this publication. After installation, the data collection plays a significant role as the data has several parameters. This research can be helpful for the procurement, preparing, capacity, the executives, examination, observing, and estimate of much information in renewable energy systems. For design purposes, three different

models have been considered which are named as a proposed system. The design method of the proposed system shows the successful model which can serve as a decision support system for implementing a photovoltaic system in rural areas with limited capacities.

Problems associated with Planning

According to the International Renewable Energy Agency (IRENA), as many as 30 countries in Africa have electricity outages because supply lags demand. Africa Needs Electricity Now More Than Ever, Especially to Keep Covid-19 Vaccines Cold [Forbes, May 2, 2021]. In the renewable energy sector, the major problem is feasibility analysis. If we are designing a renewable energy system, we must always focus on the critical points of that sector. Sustainability or the energy sector cannot only save CO_2 emission, but also it can be a source of grid autarky. Gird autarky means reducing the usage of fossil fuel-based energy systems. In that regard, we also need to consider the system's stability based on an off-grid mode. As we said about the uncertainty of the weather, we cannot assure that how much energy demand can be fulfilled in the upcoming days. For that reason, scientists are doing much research based on the data collected from the system. In our research, we would like to make a simple guideline that can be understandable from the users' point of view regarding installation. The energy system needs to be fulfilled the demand. If we can design a system including the conventional energy system in the addition of renewable energy sources, it can be beneficial in different ways. It can minimize the load into renewable-based sources such as Photovoltaic (PV), storage system, and connected Inverter for AC appliances. An inverter can be a source of Total Harmonic Distortion (THD). An additional grid-connected system could be helpful to eliminate the THD in peak load conditions.

Objectives and Aims

The objective or contribution of the research will be to combine necessary resources and ensure the stability of a hybrid system. One has to check the current electricity price and current electrical facility of the area where they want to establish a project. For our design, we choose the country where they have different electricity prices of that area as a reference. For the analysis part we used an example of PV system installation in a specific location. As hybrid system can be installed in a different from and the calculation is based on their specification. To get a better result, the calculation needs to be done based on a system compared with a different option. In that scenario proposed system (I) is taking as a base system and it will be compared with proposed system II and III. The electricity price will be taken as a reference for the proposed system I, and we will take the household Tariff. If the energy requirement is more than 500 kWh (https://portal.edm.co.mz/) in that area, the total requirement of cost is around 0,12€/kWh and general tariff as a reference system. We choose the electricity price of Mozambique as a reference area. One can take his region during the planning and calculations for an individual design purpose. For proposed system II, the combination will be a solar system with the Grid connected inverter. For the proposed system III, the combination will be a PV system as an off-grid system.

In this research, we aim to visualize the data which can be created or forecasted in the contrast of project lifetime. The data has been contained with different parameters such as Diffuse Irradiation, Maximum Power Point (MPP), Voltage, Maximum possible PV Energy, Usable PV Energy, Backup Generator Energy, Cable Losses, Losses due to charging/discharging (Charge standalone inverter, Discharge standalone inverter). We will use different data analysis tools to visualize the data. Some machine learning tools will also be used to analyze the collected data. The simulation model has been created by using software tool *PVsol* [9] and the data was also extracted from that tool which can be used for the analysis part. In the machine learning part, the accuracy of our predictive model will also be analyzed as a prediction of a parameter. In that research we have a stored data which is representing an hourly data of 8760 values.

But if the data is a real time data and it is generating continuously then the volume of the data will be so high that we need to use different big data tools to analyze the data. We will also discuss this topic for further research perspective in our research.

Technical plan

In the technical design of the system, load profile measurement is an important part. Load measurement can take the current electricity demand according to the community or the area. Load measurement or power distribution quality is essential for identifying the area's current condition. If the power quality of the grid in the local area is not stable, we can see the output from the harmonic distortion of the area. Harmonic distortion is a mechanism from which we can find the purity of the sine wave in an electrical system. There are different types of energy meters available, and some make monitoring energy usage from where we can check the output as such power factor, active power, harmonic distortion [5]. That can be overviewed to check whether there is any load shedding if the THD is higher, which also tells us the power quality. Another way of load calculation is to identify the electrical consumption by using the electrical bill of that area. Finally, we have to determine the total energy demand and the number of appliances we are running. The Electricity consumption in the research area is taken around 370.18 kWh Per capita. In Germany, this is an average of 6,445 kWh. If we consider five people in a household, the total requirements will be 1850 kWh/year for a single household. If we consider a small community with 50 households, it will be 92,500 kWh/year. All values were taken as an example by considering the home and regular appliances in a community. The following input parameters were considered during the planning and calculations for proposed system II.

- Assessment period: 20 years
- Tax rate: 15%
- Financing: Bank Loan
- Loan Capital: 100%
- Term: 10 years
- Interest rate: 4%
- Cost of system setup and labour: 1,265 €/kWp
- Price of Electricity sold to the third party: 0.05 €/kWh
- First Solar –FS 270 Q211
- Cell Texture-CdTe
- Horizontal and Vertical distance 0.30 m
- Mounted-Open Space
- Mounting angle 30°
- Mounting support clearance 1.118 m

Design strategy of the system

As we used two basic systems for the hybridization purpose, the first proposed system (II) was based on a grid-connected mode, and the second (proposed system III) was based on an off-grid system with a backup generator. Therefore, the general parameter for each system was considered a constant number, and it was compared between them.

From the table below, we can see the output of the proposed systems II and III, where we can also see the general input taken for system III. (System I was only based on local electricity price). The output is the suggestions from the simulation tool that which system is better in terms of financial and economical perspective to design the hybrid systems.

Type of System	Grid-connected PV System with Electrical Appliances System II	Stand-alone PV System with Backup Generator System III
Total Consumption	92,500 kWh	92,418 kWh
Load Peak	10.6 kW	10.6 kW
Module Data	FS-270 Q211	ASM6610M-300 PENTA Premium
PV Generator Output	22.4 kWp	14.4 kWp

Table 1: A comparison between Proposed system II and III

Inverter 1	STP10.0-3AV-40	Sunny Boy 6.0-1AV-41
Configuration	MPP 1+2: 16 x 10	MPP 1+2: 2 x 12
Total Battery Power		634 kWh
Inverter		3 x Sunny Island 4.4 M
Battery		120 x BPE-LFP-H5

Table 2: Inverter and battery size comparison between system II and III

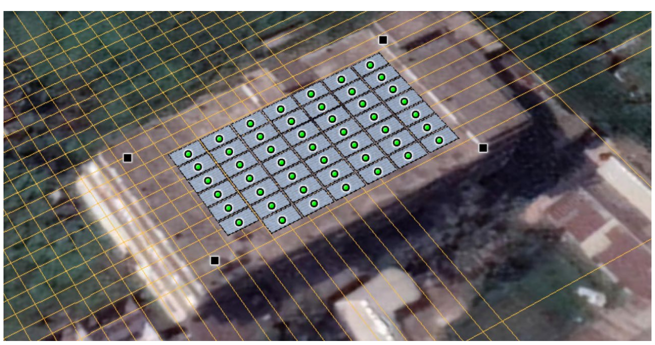

Figure 1: An overview of a 2-D model during the simulation (PVsol)

From the above figure we can see the simulation diagram which was created during the plan of off grid. The calculation was done by using different parameters which has been discussed in our technical planning section.

System design

During the design of the system (*Table 1*) 14.4 kWp which was proposed by the system III as per the requirement of energy requirements. To install such system the total requirement of the area could be around 78.5 m^2 which is 5.45 per sqm area for 1 kWp. For the system II, Ground reflection Albedo factor was around 40.38 kWh/m^2.

Global radiation at the module was counted around:
1,982 kWh/m^2 x 230.4 m^2 = 4,566.53 kWh [10],[13].

Rated PV Energy depends on the multiple factor such as partial shading, mismatch configuration and deviation from the nominal temperature. For proposed system III configuration section, the PV energy DC for Inverter 1 was 20,492.96 kWh and for inverter 2 it was 20,488.41 kWh which was the energy at the inverter input. PV energy AC grid was around 20,008.11 kWh. In that configuration the PV energy. In our design the AC side power requirement was 230 V for both systems. That means a single-phase voltage was 230 V where V_{LL} (Line-Line voltage) was equivalent to 415 V AC. The equivalent DC voltage should be around:
$V_{dc} = \sqrt{2} \times 230 = 324.3$ V.

MPPT (Maximum Power Point Tracker) was used to evaluate and match the Inverter's input voltage from the strings. We must constantly monitor the voltage coming from the open-circuit voltage V_{oc} of the PV module, and it was in a combination of 12 modules each in one string. It can produce up to 475.32 V as an input to the Inverter. The inverters supply three-phase voltage, which supplies 415V in the community. Also, various distribution boxes feeding different building sections are supplied from the main distribution box. The meter reads the amount of power generated by the PV system and the amount supplied to the grid (if it is a grid-connected system) [8].

The maximum voltage can be held by inverter charger up to 600 V. The voltage generated was in the *MPPT* range of the inverter 210-500 V [11]. That means if the inverters can operate in this range, they can give a better output. The output of the PV array will not be constant as MPPT will always try to operate at its maximum point. Because of the uncertainty the voltage is always optimized by the buck-boost DC-DC converter which regulated the voltage to meet the require voltage of the inverter [8]. Below we can see the system configuration for proposes system III:

Battery Charging	10,804	kWh/Year
PV System	242	kWh/Year
Backup Generator	10,562	kWh/Year
Coverage of Consumption by the Battery System	9,439	kWh/Year
Losses due to charging/discharging	1,352	kWh/Year
Losses in Battery	647	kWh/Year
Cycle Load 1	0.3	%
Service Life 1	>20	Years

Inverter Size calculation for System III	
Model	Sunny Boy 6.0-1AV-41
Manufacturer	SMA Solar Technology AG
Quantity	2
Sizing Factor	120 %
Configuration	MPP 1+2: 2 x 12

Diesel Genset production for System III		
Total Consumption	92,484	kWh/Year
Covered by PV power	22,473	kWh/Year
Covered by battery	9,439	kWh/Year
Covered by auxiliary generator	60,572	kWh/Year
Solar Fraction	24.2	%

For the system design III, the backup generator has a rated power of 8.83 KVA and the total current drawn by 38.4 A. During the dimensioning of Battery Inverter, the total power was calculated around 13.3 KW and the total battery power was 132,000 Ah which is equivalent to 633.6 kWh. Energy at the inverter 1 input was 11,775.28 kWh and inverter 2 was 11,774.43 kWh.

The solar fraction of the system was calculated by E_{PVuse} in relation to the load requirement E_{Last} [10] where it was 24.2%. The Performance ratio of the system was also calculated by the formula: Performance ratio= E_{PVuse} / E_{in} * η_{STC} [10].

The performance ratio measures the energy losses in the system which occur in comparison with the energy output of the PV array under standard test conditions (STC). From Table 3, we can see the result around 84.7%. The output under STC is determined by the energy irradiated to the PV array surface (E_{in}) multiplied by the module efficiency under STC (η_{STC}).

The performance ratio describes the efficiency of the photovoltaic energy which can potentially be generated in each system environment. The system efficiency measures the conversion of the total energy irradiated to the array surface (E_{in}) by the PV system. System efficiency is also an essential part of planning a hybrid system. It can be observed by the PV array and the inverter and considers cabling losses and battery losses. The formula of the System efficiency calculation is done as follows:

System efficiency = E_{PVuse} / E_{in} [10].

The number of devices in three-phase systems can also be determined based on the 30-minute power of the Sunny Island inverter. It can be determined that how many inverters are needed during the system design, and it can be also determined as follows: P_{max} = 14.4 kWp/6 KW = 2 number of Inverter (Sunny Boy 6.0-1AV-41).

If we consider our System III with a diesel generator, with an autonomy time of 2 days the battery Size [kWh] can be calculated as:
Battery Size [kWh] = (2 x (92,418/365))/0.9 = 562.66 kWh (considering annual energy requirements of 92,418 kWh, autonomy days =2, Efficiency =90%). If we consider the size in terms of [Ah] then it will be around:
Size in [Ah] = Battery Size [kWh] x 1000/48 V where 48 V is our system voltage from battery. In our system we have cell voltage is around 3.2 V with a no. of cells in series of 15 (*from the datasheet generated from PVsol*). Overall, 120 number of strings being considered, and each string of the battery can be connected through three Sunny Island 4.4 M battery inverter [12].

From the below table we can see the comparison output between two proposed systems.

Type of System	Grid-connected PV System with Electrical Appliances	Stand-alone PV System with Backup Generator
Performance Ratio (PR)	88.2 %	84.7 %
Grid Feed-in	8,937 kWh/Year	not applicable
CO_2 Emissions avoided	18,788 kg / year	10,003 kg / year
Standby Consumption (Inverter)	38 kWh/Year	38 kWh/Year

Table 3: Performance ration comparison between proposed system II and III

Electricity Production Costs	0.04 €/kWh	0.06 €/kWh
First year savings	6,884.40 €/Year	not applicable because its not compared with grid

Table 4: Economical comparison between proposed system II and III

The reason for performing a comparative analysis between two hybrid systems is to make a single analysis applicable to more than one installation. The analysis can be done between more than two models too.

Agri-Voltaic in Hybridization

In hybridization, Agri voltaic could also be an opportunity to reduce the loss of land usage. A few factors need to be considered during the plan of Agri voltaic during the cultivate crops underneath the solar panel. The different solar panel has their temperature and abortion level in terms of irradiation. Each crop has its saturation level at which it can grow and give a better production. Generally, with increasing the flatter angle of the incident, the reflection losses at the module surface also increase. For settlement and farming for the cropland albedo, 20% was considered for our all planning. The radiation reflected from the ground to the module level is calculated as follows:

RTI=GHI (Global Horizontal Irradiance) $\cdot\rho$A (Range of Albedo) *0.5(1−cos (γM (tilt angle))) [13].

Surface	Range of Albedo ρA
Fresh snow	0.80 to 0.90
Old/ Melting snow	0.40 to 0.80
Desert Sand	0.40
Grassland	0.25
Deciduous Trees	0.15 to 0.18
Coniferous Forest	0.08 to 0.15
Tundra	0.2
Ocean	0.07 to 0.10

Table 5: Range of Albedo in difference surface of the installation

The albedo irradiance contribution is proportional to the Global horizontal irradiance, with proportionality factor=0.5*(1-cos(tilt)). This means that for a horizontal plane its contribution is null (the plane doesn't "see" the ground), and maximal for a vertical plane (factor0.5*(1-cos (90°)) =0.5).

For a plane at 25°tilt, it would be 0.5 * (1-cos (25°)) = 0.5 * (1 - 0.906) = 0.047, i.e., 10 times less [9].

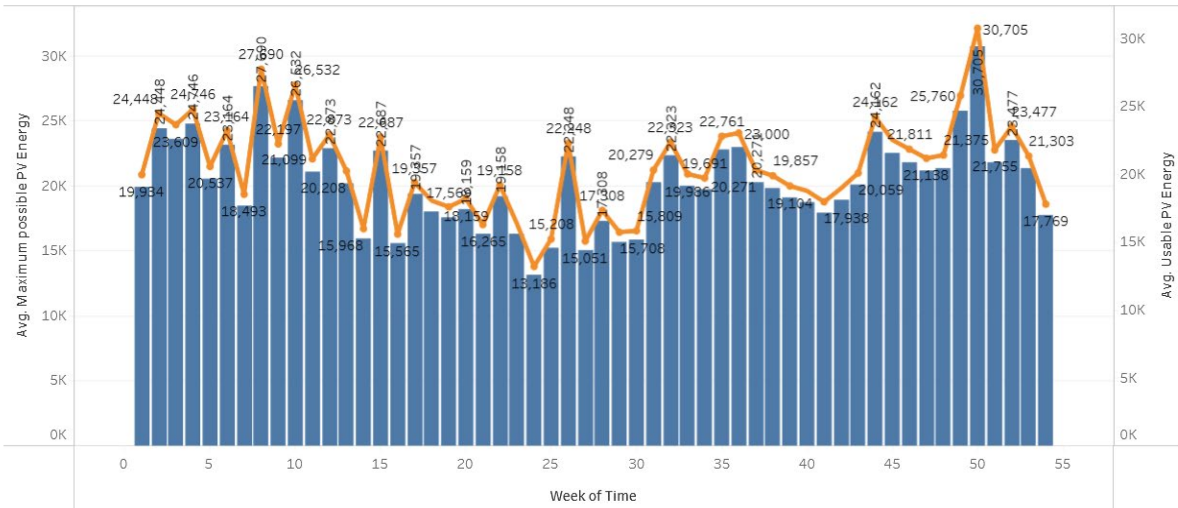

Fig 2: PV energy comparison by using tableau (Maximum possible PV energy and Usable PV energy)

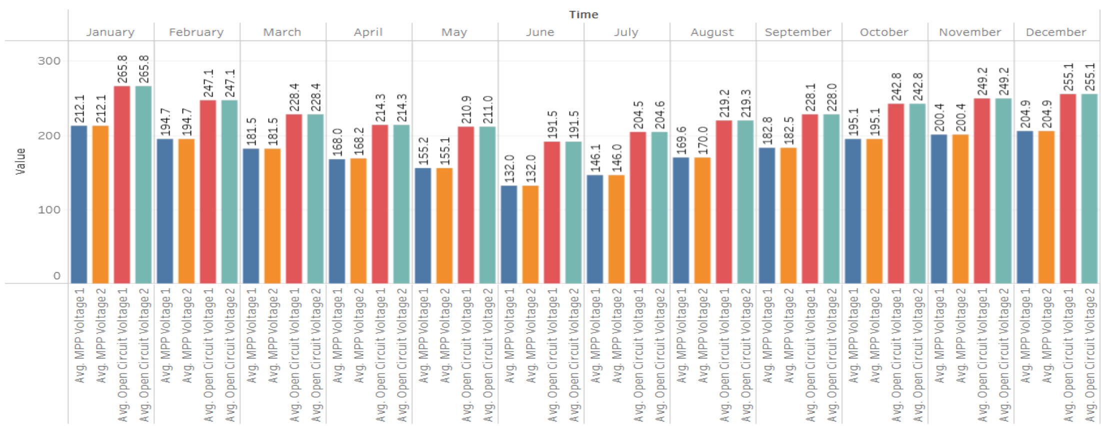

Figure 3: MPP Inverter 1,2. Voc visualization in a monthly basis by using their average values

Data Analysis and Visualization

In such circumstances, data analytics projected renewable energy forecasting approaches are being investigated for improved regulation and dispatch planning. For financial purposes, traditional distribution system power meters only employ data that has been manually gathered and evaluated. While the massive volume of data gathered from a microgrid from many resources nowadays necessitates the use of modern data analytics to extract vital information not just for financial purposes but also for the health of the energy network. High-resolution consumption data for demand forecasting and energy generation optimization. A system must have predictive maintenance and problem detection based on data analytics and sophisticated metering infrastructure [1].

From *Figure: 2,* we can see the *average maximum possible PV energy (blue line) and the avg. usable PV energy in (kWh) y marked as orange line in* proposed system III. The data collection is essential to see the system's status in a real-time factor. We have the time-series data on the X-axis and the Y-axis, we can see the total voltage produced in the total system. We can also visualize the hourly data extracted from the tool and compare the consumption of PV and energy coming from the backup generator. The algorithm used in *PVsol* software is mainly on direct consumption, which is directly covered by PV energy. The batteries cover the discharging consumption. It can cover up to the limit of the battery system. All required parameters are visualized in *Figure: 3* to understand the data better which is indicating the average MPP voltage from inverter 1 and inverter 2 and it compared with the average open-circuit voltage of inverters 1 and 2. The rating of the voltage is defined in Y-axis in terms of voltage [13].

Typical data analytics approaches, such as neural networks, linear regression, and decision tree, might be used to analyze information from the hybrid system. A data analytics algorithm could be helpful to mitigate some of the difficulties of the extensive data in PV or other sources connected to the systems. As we know, renewable energy sources' massive daily data can be stored. It can be analyzed and visualized to predict the future production from the renewable sources grid, which will optimize the loss in the system. It can also help us by visualizing to understand the system efficiency, losses, production scheme and in various ways which will explain in the benefits section of this paper.

If the production decreases, it will maximize the costs of electricity (if connected to grid) because to meet up the demand, we need to provide more supply to the system. Therefore, predicting the parameter mentioned above can be identified, and losses can be minimized. In our research, the data analysis part is analyzed based on the parameters generated during the planning process, as an example. The PV output is related to STC efficiency and with the output temperature coefficient. Inverter MPP tracking is also related to the MPP voltage of the modules connected in series [13]. The high Irradiation can achieve an MPP power, and lower temperature (can be done by orientation and inclination of modules) as we know temperature higher than the STC will create losses in the system's output. Also, it needs to be checked the maximum occurring voltage, which is essential as an inverter system, voltage and it should not be higher than the limit. As in our proposed system III, the backup generator has been used, and it needs to be monitored that the AC output from the inverter should be sufficient to deliver the AC appliances.

For that reason, in this section, the data can be processed and analyzed using different methodologies such as regression model, classification model, and deep learning to identify how much energy was produced from a renewable source based on the input parameter mentioned in *Figure: 4*.

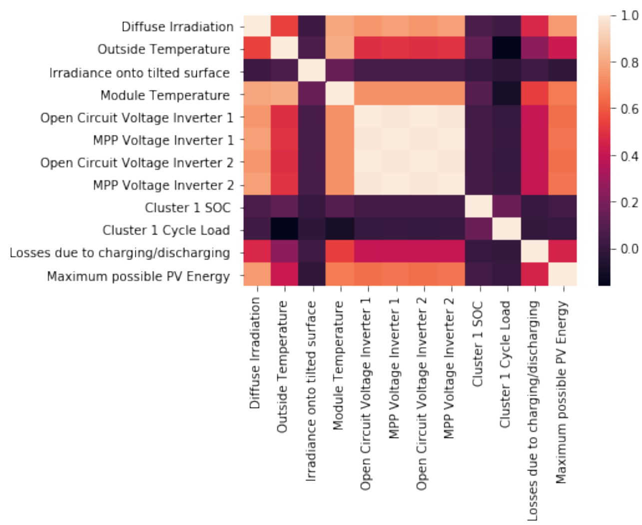

Figure 4: Data visualization by using Machine learning algorithm to check the correlation between all parameters

From the above figure, we can see the correlation between all parameters regarding the output generation. As we can see from the figure, most of the parameter correlates with the maximum possible PV energy.

Model	MAE	MBE	RMSE	R^2-score
Linear Regression	11033.96	67.29	19430.22	0.59
ANN-Regression	11316.45	594.23	19703.22	0.58
Decision Tree	4747.65	-520.89	16739.51	0.70

Table 6: Output result after using different Machine Learning approach during the data analysis

During the research, several essential data collection parameters were discussed in the significance of the data collection part. From *Table 6,* we can see the output generated during the data analysis part. The above-mentioned machine learning algorithms were imposed to identify the correlation, mean absolute error, root means squared error, and R^2-score [15],[16]. R^2 coefficient of determination is a statistical measure of how well the regression predictions approximate the real data points. An R^2 of 1 indicates that the regression predictions perfectly fit the data. In terms of predictive analysis, all these parameters are essential to calculate the model's accuracy. The data used during the analysis was based on yearly data with 8760 hourly values. In modern days the data is mostly real-time data that can be monitored from a data storage system [18].

For real-time data, the volume of the data could be higher, and, in that case, big data can play a vital role in that. In the research, we will use a big data tool, spark, for the data analysis part to check the difference between the methods mentioned in *Table 6.* This section has also discussed the importance of extensive data analysis and its outcome. A general machine learning algorithm based on *pandas'* data frame does not support distributed file systems.

The model can be evaluated with data with a specific volume and should run in a single machine. On the other hand, *PySpark* runs on multiple machines. *PySpark DataFrame's* are distributed in the cluster (meaning the data in *PySpark DataFrame's* are stored in different machines in a cluster). The process in *PySpark* executes in parallel on all machines. If someone has to be working on a Machine Learning application dealing with larger datasets, *PySpark* could process operations faster than Pandas. *PySpark* is a Spark library written in Python to run Python applications using Apache Spark capabilities.

Using *PySpark*, we can run applications parallelly on the distributed cluster (multiple nodes) or even on a single node. Apache Spark is an analytical processing engine for large scale powerful distributed data processing and machine learning applications. Spark was written in Scala, and later, its API *PySpark* was released for Python using Py4J. Py4J is a Java library integrated within *PySpark* and allows Python to interface with Java Virtual Machine (JVM) objects dynamically; hence, to run *PySpark,* Java, needs to be installed with Python Apache Spark [14],[18],[22].

The following *Table: 7* shows an output of simple linear regression, which has been analyzed based on the dataset used for *Table: 6.*
The value is the prediction of Maximum potential PV energy in the prediction column, which was the target value during the process.

features	prediction
(11,[1,3,8,9,10],...	1870.74044
(11,[1,3,8,9,10],...	1998.68398
(11,[1,3,8,9,10],...	1588.59260
(11,[1,3,8,9,10],...	1439.10275

Table 7: Output result after using PySpark Machine Learning approach during the data analysis (Linear regression)

MAE: 10418.508980764906
MSE: 337551753.7186591
RMSE: 18372.58157469056
R^2 0.631645400414456

Benefits of Hybridization to Renewable Energy Sector

In hybrid system design, financial analysis plays an important role also to determining the outcome from the system. To calculate the cost of electricity (*Table: 4)*, the total investment costs need to be divided by project lifetime and annual costs needs to be added. The total costs need to be calculated as a ratio of PV generator energy [10]. In system II, the savings were around 7,331.2 €/Year, and energy from the Grid was taken around 61,461 kWh/Year. In that system, the performance ratio was 88.2%, and the Feed-in grid was around 8,937 kWh/Year. Specific Annual Yield was taken around 1,784.62 kWh/kWp. According to that system, the PV Generator output was around 40,014 kWh/Year. The formula for the Net present value of the total investment is as follows:

NPV = Σ [CV of the price-dynamic payment sequences over the lifetime] - investment + subsidies.

A positive net present value indicates an investment that can be assessed as economically positive. The following applies to the electricity production costs:
[Electricity production costs] = [annual costs Z] / [annual electricity generation] [10].

For proposed system II, the module was different and connected to the Grid. The return of the asset was around 26.39 %. The following electrical costs were considered a reference 1 kWp system, and it was average 1,265.04 € per kWp. The costs were included with the following parameters:

1. Mounting of the system = 50 €/kW
2. Module costs = 270 € (for 1 kW)
3. Surge protection = 10 €/kW
4. Cable DC -6 mm^2 = 6.14 €/kW (5.63 € for each meter, we need to calculate the total length in m)
5. Cable AC – NYY 5 x 10 mm^2 = 11 €/kW (9.9 € per meter, we need to calculate the total length in m)
6. Transformer connectivity (3-phase) = 200 €/kW
7. Module clamp = 12.5 €/kW
8. DC mounting = 218.18 €/kW
9. AC mounting = 204.5 €/kW
10. Installation and others = 272 €/kW
11. For 1 kWp (cost is around 1,265.04 €), If we are calculating the total cost, we have to consider the cost of the Inverter too during simulation.

Conclusion and Future Works

In the system design, it was clear that the proposed systems II and III have less cost of electricity in a comparison with the cost of the utility grid. As it was mentioned earlier this research could be helpful for the consultant or a renewable energy service provider if they would like to establish a project in a rural area. The input parameter which was taken was taken as an example. The input parameters should be changed according to the need of the local authority or the customer. A few important points which need to be considered is that the capital expenditure of the equipment. In our research, the cost was also taken as an approximate number which is also variable. If someone would like to install such a hybrid system he should consider the load calculation, cost of electricity at utility grid, cost of the equipment such as the battery, inverter, modules, cables, and different protective devices. In terms of financial parameters, the interest rate, tax rate, demand charge, operational and maintenance costs, project lifetime should also need to be considered. As we know stability is also a problem in terms of renewable because of its uncertainty, one should also consider an intelligent inverter that can be controlled to maintain stable voltage and frequency [8],[11],[12],[17]. Synchronization of the inverter with the grid (example system II) can be achieved using a Phase-Locked Loop circuit. A phase-locked loop (PLL) is an electronic circuit with a current or voltage-driven oscillator that continuously adjusts the inverter signal to match the phase and frequency of the utility system. The phase-locked loop generates an error signal when the output waveform of the inverter is not in phase with the utility supply. The inverter uses this error signal to synchronize (locked on) its output waveform with the grid/utility supply [17,[8]. It is always beneficial if communication and information technologies are added for energy production, which can be used for cost reduction and efficiency. If the strings (PV strings) parallel connection consists of three or more in design, then string overcurrent protection need to be provided to protect modules and conductors from excess current fault [8].

A hybrid system would allow for a seamless transition to renewable energy, more sustainable utilization, and a less polluted environment by connecting energy suppliers and customers. A machine learning mechanism can be used to forecast the system's energy supply. Predicting the future energy, output excess energy could also play a vital role in analyzing possible technical problems like grid instabilities and economic feasibility [19], [20]. In this research, the key elements have been discussed, and the processes were explained in terms of a hybrid system that can be established in rural areas and provide more grid stability by combining more than one source.

An essential point is the maximum possible energy and useable energy from the renewable source in a hybrid system. It could be added value in financial analysis because the uncertainty of the renewable source is the issue if we compare it to the conventional energy-providing systems. If we can predict future uncertainty to some extent, it would be possible to control the supply and demand in peak load conditions [20], [21].

To ensure and overcome the situation such as grid fault or a problem in a hybrid system, using different kinds of data analytics methods can identify the system efficiency as discussed in the data analysis part. Sometimes it is difficult to find the problem in a specific device such as inverter, string, or losses in a system. By analysis the collected data either from sensor data or data collected from the energy meter. The data can be analyzed and visualized to check the system condition. Machine learning or predictive analysis is the tool that has been used for prediction-based collected data. As the prediction tool is also uncertain, it has been compared with different models to see the accuracy of the algorithms.

A conclusion we can say that there are a lot of opportunities for renewable energy-based hybrid systems and tools like artificial intelligence, data collection plays a significant role in it. To install a system physically beforehand the feasibility analysis is an important part and in our, we have also seen that the costs, productivity, and other factors are also key elements on it. For future work, the sensor technology can be implemented in this research by installing it practically.

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