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Identifying and Analyzing the Technical Challenges of Grid Tide Inverters for PV System: A Case Study of Ethiopia and Zambia

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Zambia and Ethiopia are two countries from southern and eastern of Africa due to their geographical location and other factor the environment condition is different. The research aims at identifying and analszing the technical performance issues of Grid tide Inverter (GTI) for PV system due to operating climate and others factors. In Zambia the study focused on the two main solar plants which is under ZESCO national grid at malty facility zone (MFZ), the first one is the 54 megawatts Bangweulu solar power plant by Neon Investment of France, second one is 34MW Ngonye solar photovoltaic (PV) plant. In Ethiopia eight min off-grid site under Ethiopian Electric Utility(EEU) is included. Beltu, Behima, Mino, Ungoge, Korhele,Tum, Omorate and Kofetu. A survey is conducted focusing on identifying and analyzing the technical performance issues of GTI in the above-mentioned area.

Using Microsoft excel the environmental \climate condition, Solar radiation, Air temperature, Rain falls and Wind of the two country Zambia and Ethiopia is investigated and analysedfor each

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selected site. A questionnaire and a Sime structure interview is conducted. The basic inverter challenges are investigated from the collected data and the problem is analyzed based on the specific inverter data sheet. The data sheet of the inverter for each site under this study.
Finally, the real-time performance of the inverter of the off-grid PV mini-grid system installed in a small remote town in Ethiopia and on-grid PV system from Zambia at multi facility zone is analysed using measured meteorological data. From on- grid and off-grid inverter performance challenges, which the researcher collected from different plant the main ones are climate or environmental effect and also over load. Overload is one of the frequent challenges in koftu, behama and amorita this can be due to high population growth and unexpected power demand from the community.
Environmental condition affects almost all solar plant site which is under this study. If we compere the climate of east which is Addis Ababa Ethiopia and southern of Africa Zambia Lusaka. The temperature of Lusaka is higher than Addis Ababa by 5.63°C and even in the plant under this study, temperature rise is one of the challenges on the inverter performance, sensitive electronic component bent due to excessive temperature.
On the other side in Ethiopia Addis Ababa excessive rain affect the inverter. Finally, Addis Ababa has about 1.32 times more rainfall than Lusaka, (Addis Ababa's 79.54mm vs Lusaka's average of 60.34mm). For that reason, most of the inverter in Ethiopia on the mini off-grid site are affected by heavy rain condition.

Keywords: Solar PV; GTI (Grid Tide Inverter); EEU; beltu; behima; mino; ungoge; korhele; tum; Omorate and Kofetu; MFZ.

1. INTRODUCTION

"The electricity demand in the world's developing countries is increasing rapidly, and it is a great challenge to meet this demand" [1]. "To balance the energy demand and generation, renewable energy resources such as Photovoltaic (PV), Wind, and Biomass could be a good solution. Among these, solar energy is considered to be one of the most useful sources because it is free, abundant, pollution free and less maintenance fee. Since the generated voltage from PV is DC, inverters are required to convert DC voltage from PV to AC before connecting it to grid or electronics equipment. The output voltage and frequency of inverter should be same as that of grid frequency and voltage" [2]. "The work done related to PV grid connected systems published so far reveals how an inverter should be designed and output should be synchronized with the grid or any standalone solar pant" [3]. The inverter is what converts generated energy into deliverable power. The inverter may have different challenges due to faulty installation, harsh temperatures/ environmental factors and others. It will undoubtedly suffer in performance, passing the cost of that lost efficiency on to the end customer. Because every application is unique, there is no one-size-fits-all solution to inverter challenges. Solar farm operators should have an awareness' of this fact when selecting a solution, and know what questions to ask the manufacturer in relation to basic inverters challenges airflow / cooling, environmental protection, operations and maintenance concerns.

"In fact, the renewable energy sources such as photovoltaic offers greater supply security to consumers while respecting the environment and could be a good solution to balance the energy demand and generation" [4,5]. "Several researches have been conducted on the grid-connected photovoltaic systems in the use of photovoltaic energy effectively" [6,7]

The continuous increase of electricity demand needs to be supplied with alternative power plant. Solar energy is the best solution to fill in the gap; it is a free energy source available in everywhere. The inverter is what converts generated energy into deliverable power. Solar farm operators should be cognizant of this fact when selecting a solution, and know what questions to ask the manufacturer in relation to inverter installation, and take in to considerations, some of inverter's challenges like inverter beeping, the MPPT modules, operating climate, Airflow/cooling, environmental protection, operations and maintenance concerns, and EMI (electromagnetic interference) shielding [8]. Doing so will ensure their inverters will continue to deliver power efficiently over an increased lifespan [9]. Especially for developing countries like Ethiopia and Zambia it need to be protected from harsh temperatures for which we can able to have sun shine almost the whole year.

Solar system normally was exposed to outdoor environment, may frequently work at high and low temperature, high humidity, windy, sandy, rainy and salty environments. Inverter must adapt different operation environments, especially the harsh environments. Electricity generated by PV systems need to be converted to an alternating current (AC) in order to satisfy the specification of the utility or the load. For this, the working environmental condition of the inverter is very important.

2. LITERATURE REVIEW

2.1 Solar Power Potential in Ethiopia

Ethiopia is a country of great geographical diversity. Located within the tropics, its physical conditions and variations in altitude have resulted in a great range of terrain, climate, soil, flora and fauna.

According to GIS-based MCA (Multi criteria analyses), the eastern part of the country is relatively suitable for larges cale solar panel installations. It has 1.9 MWh/m2 /year of solar radiation on average with ideal 30 land cover for large-scale solar farms. Moreover, it is the least densely populated region which also is a very important criterion [10].

2.1.1 Solar power project in Ethiopia

There aremany ongoing projects related to solar power, The Metahara solar independent power producer (IPP) project is one of it. It expected to generate 100 MW. A Power Purchase Agreement (PPA) and approval of the Implementation Agreement (IA) between Enel Power, an Italian firm, and the government of Ethiopia (GOE) is made. [12] Enel will develop and operate the project.

On the other hand, A Saudi firm, ACWA Power, has won a tender to develop two solar power projects, valued together at $300 million, in Afar and Somali regional states with a capacity of 250MW. "ACWA Power offered 2.5260 US cents/kwh for power generated at these two sites, Gad and Dicheto. There are also six other IPP solar power projects in the pipeline, but these are currently suspended due to financing related matters" [13].

In March 2022, Green People's Energy Ethiopia has conducted a series of trainings for planners and technical implementers of solar mini-grids. With more than 200 prospective mini off-grid sites in the pipeline, Ethiopia is gearing up for a massive roll-out of off-grid electrification – and for this, the capacities of public- and private sector actors are to be strengthened [14].

The Ethiopian Electric Utility currently (EEU) have 25 sites under construction among the 25 solar power mini off-grid site, 8 minis off- grid site are currently fully operating and also 201 mini off-grid sit is to be implemented up to 2027.

"Ethiopian Electric Utility EEU - Mandated for 66/45 KV sub transmission and substation operation - Distribution network construction and operation - Energy retail - Implementation of National Electrification Program" [15].

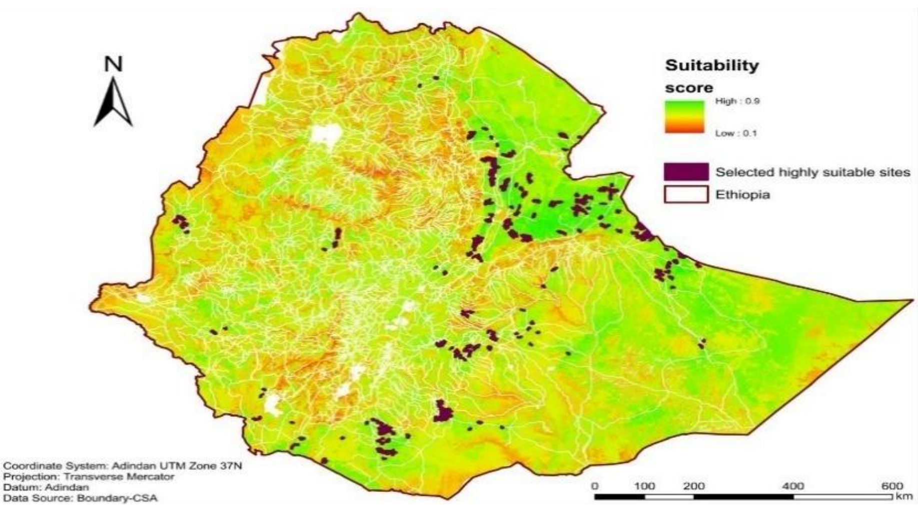

Fig. 1. Selected highly suitable sites for large-scale photovoltaic installations in Ethiopia [11]

2.2 Zambian Solar Power Potential

"According to the previous studies and data undertaken by Meteorological Department of Zambia, the country has a significant potential of solar energy for both power production and thermal from solar energy technologies. The country is situated at the latitude of 8 to 18 degrees south of the equator and longitude 22 to 34 degrees east of prime meridian with an average sunshine of about 6-8hours per day and high monthly average solar radiation incident rate of 5.5kWh/m2 /day throughout the year" [16,17].

2.2.1 Solar power project in Zambia

"The Zambian government aims to deploy 500 MW of solar PV by 2023, in order to ease chronic power shortages. The sub-Saharan country currently relies on 2.8 GW of installed power, with about 85% coming from hydropower. Its access to electricity is about 30%" [18].

"Solar PV minigrids make only a small contribution to rural electrification in Zambia, compared to hydro and diesel mini-grids.Currently, 5 solar PV minigrids (4 private and 1 public run by a cooperative) were operational and 2 public solar PV minigrids were under construction in Zambia (ranging from 10 KW to 300 KW)Most minigrids are concentrated in RGCs as they are densely populated with an average offgrid site of 110 connections. ENGIE, a private developer, inaugurated its first Power Corner (minigrid) in 2019 providing electricity access to 378 households" [19].

"Zambia had 96 MW of installed solar power at the end of 2021, with around 95 MW deployed in 2019 alone. The Zambian government aims to deploy 500 MW of solar PV by 2023, in order to ease chronic power shortages" [21].

The Bangweulu solar PV plant, with installed capacity of 47.5 MW alternating current (AC) (approximately 55-megawatt peak [MWp]), is located in the Lusaka South Multi-Facility Economic Zone, 20 km south of Lusaka, Zambia.

"It will generate around 100 GWh per year, sold to ZESCO 25-year power purchase agreement (PPA). The Bangweulu Power Company Limited is a special purposevehicle (SPV), established according to the shareholder agreement on November4, 2016, and co-owned by Neoen, First Solar, and the IDC of Zambia with 55 percent, 25 percent, and 20 percent shareholding,respectively" [22-24].

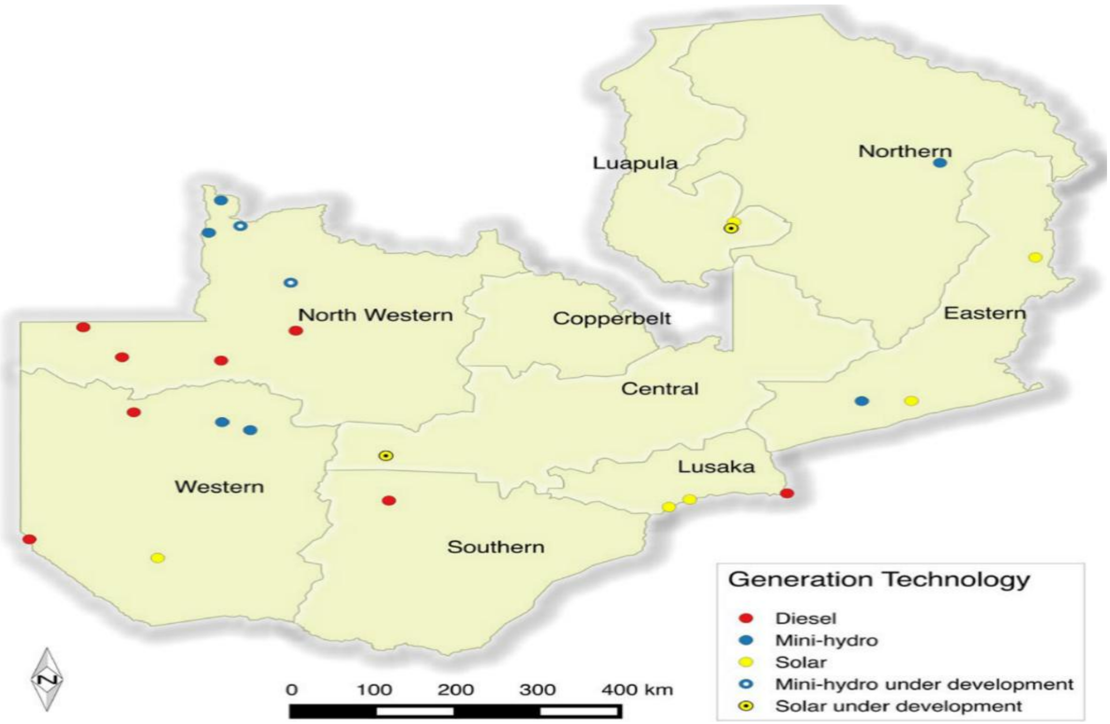

Fig. 2. Existing and planned mini grids in Zambia [20]

"The Ngonye solar PV plant with the capacity of 28.2 MW AC (approximately 34 MWp) is also located in the Lusaka South Multi-Facility Economic Zone, next to the Bangweulu project. It will generate around 61 GWh per year, sold to ZESCO under a 25-year PPA. The Ngonye project is led by the EGP. Its parent company—Enel S.p.A. (Enel) —was Italy's largest power company and Europe's second largest utility with an installed capacity of 90 GW. The EGP and the IDC signed their shareholder agreement on November 11, 2016. On April 3, 2017, the Ngonye Power Company Limited (the project company), signed a PPA with ZESCO and a Government Support Agreement (GSA) with the GRZ. The project companyis co-owned by the EGP (80 percent) and the IDC (20 percent)" [25].

2.3 Environmental Condition in Ethiopia

Ethiopia is a country on the Horn of Africa. The country lies completely within the tropical latitudes and is relatively compact, with similar north-south and east-west dimensions. The solar radiation, Air temperature, rain fall and wind of the country is included on this paper.

2.3.1 Solar radiation

The monthly and annual global solar radiations of Ethiopia were calculated from 30 m resolution ASTER Global DEM using Environmental System Research Institute (ESRI) ArcGIS solar radiation analysis tools. [26] According to the GIS model, large portion of Ethiopia receives solar radiation exceeding 1.8 MWh/m2 /year. In total, 195 sites located in different regions at 0.5 percent of the total area of Ethiopia, were selected with aggregate electricity generation potential of 65 GW per year purely from solar radiation.

2.3.2 Air Temperatures

The wide variation in elevation (the height of land above sea level) in Ethiopia produces three types of climates, illustrated in below: [28]

- The hot *Kolla* climate occurs in regions below 1500 m and has an average annual temperature of about 30–33°C with an average annual rainfall of 300–1000 mm.
- The temperate *Woinadega* climate occurs in regions between 1500 and 2500 m and has an average annual temperature of 16–29°C with an average annual rainfall of 400–2400 mm.
- The cool *Dega* climate occurs in regions above 2500 m and has an average annual temperature of 10–16°C with an average annual rainfall of 1000–1600 mm.

2.3.3 Rain falls

Rainfall in Ethiopia is the result of multi-weather systems that include Subtropical Jet(STJ), Inter tropical Convergence Zone(ITCZ), Red Sea Convergence Zone (RSCZ), Tropical Easterly Jet(TEJ), and Somali Jet [30] This makes the rain fall system of the country fore complex.

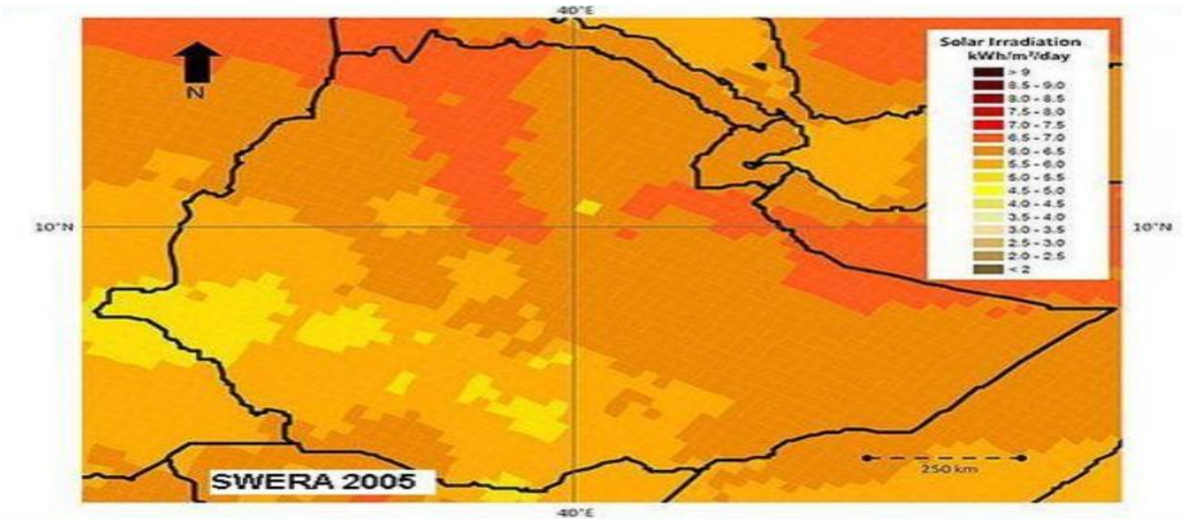

Fig. 3. Solar radiation in Ethiopia in (KWh/m²/day) [27]

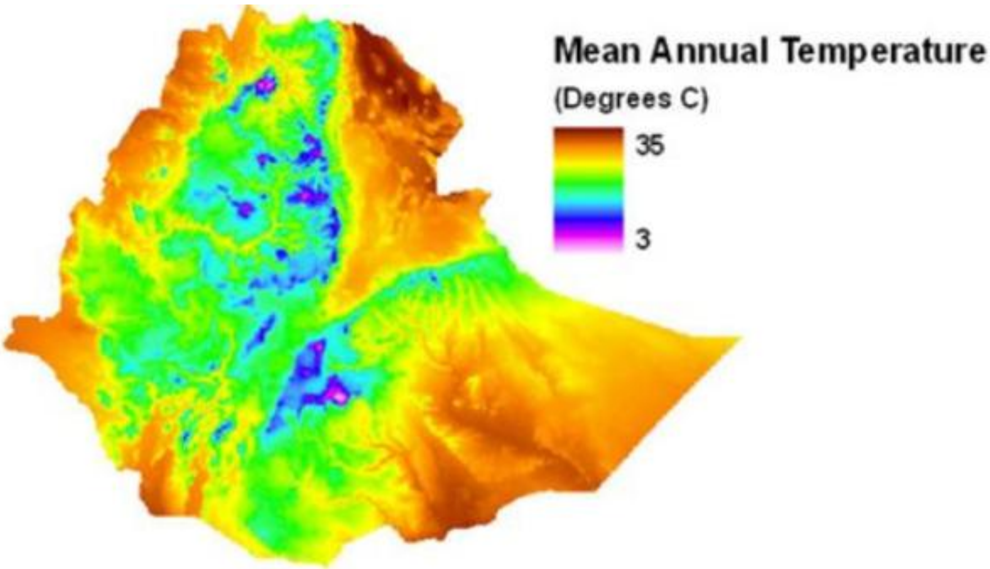

Fig. 4. Mean annual temperature [29]

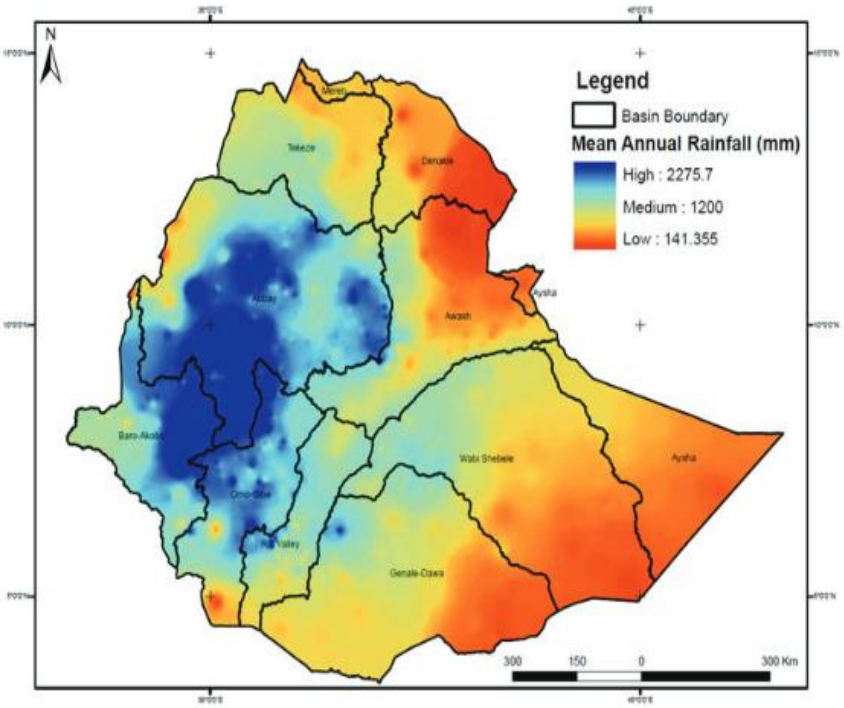

Fig. 5. Mean annual rainfall (mm) [31]

2.3.4 Wind

Ethiopia has good wind resources with velocities ranging from 7 to 9 m/s. Its wind energy potential is estimated to be 10,000 MW [32] (see Fig. 5). The Ethiopian National Meteorological Services Agency (NMSA) began work on wind data collection in 1971 using some 39 recording stations located in selected locations. Ever since the establishment of these stations, wind velocity is measured and data made available to consumers. However, the number of stations established, quality of data (in terms of comprehensiveness) and the distribution of the stations leaves much to be desired.

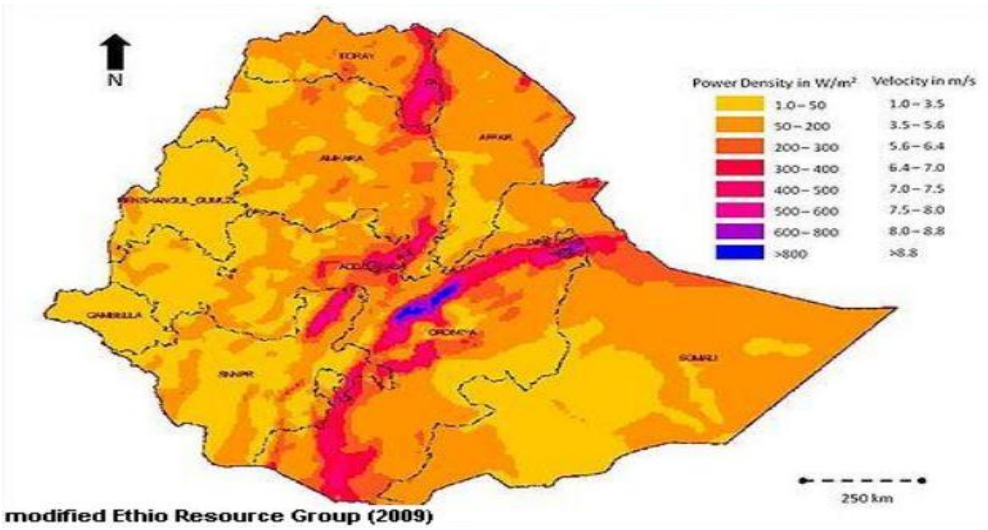

Fig. 6. Annual mean wind power density in W/M^2 and velvety in m/s [33]

2.4 Environmental Condition in Zambia

"Zambia is a landlocked country in Africa. It is situated on a high plateau in south-central Africa and takes its name from the Zambezi River, which drains all but a small northern part of the country" [34]. The solar radiation, Air temperature, rain fall and wind of the country is included on this paper.

2.4.1 Solar radiation

The country has an average 2,000-3,000 hours of sunshine per year. Average irradiation is 5.5 kWh/m^2/day, with northern areas recording the highest global solar irradiation, of 2,300 kWh/m^2/year [35].

2.4.2 Air temperatures

"Knowledge of air temperature is important, as it determines the operating environment and performance efficiency of solar power systems. Air temperature is used as one of inputs in energy simulation models" [37]. "In case of PV power plants, air temperature determines energy conversion efficiency in the PV modules, and it also influences one of the main components (inverters, transformers, etc.)" [38].

"Increasing air temperature has negative influence on performance of PV systems. The temperature data in time series are derived from CFSR (climate forecasting Reanalysis) and CFSv2 01Apr2011 - Present meteorological models by Solar GIS (geographic information system) post-processing, and they represent regional climate patterns rather than local microclimate. This means that extreme values may be partially smoothed and they not always well represent the local microclimate". [39] The temperature maps are developed only using the CFSR model data for Zambia in Fig. 8 are shown.

2.4.3 Rain falls

Mean annual rainfall ranges from 500 to 1400 mm annually, depending on the location within Zambia. The map below (Fig. 9) illustrates mean annual rainfall in Zambia from the period 2000–16, showing annual rainfall as low as 500 mm in the south and as high as 1400 mm in the north and northwest of the country [40].

It displays three zones over the 2000-16 period constructed by tracing natural breaks in the climatological data. These rainfall zones range from dry (zone 1:800 mm annually) to intermediate (zone 2: 800-1000 mm annually) to wet (zone 3: .1000 mm annually).

2.4.4 Wind

The windier part of the year lasts for 4.2 months, from July 13 to November 21, with average wind speeds of more than 9.6 miles per hour. The windiest day of the year is October 4, with an average hourly wind speed of 12.7 miles per hour. The calmer time of year lasts for 7.8 months, from November 21 to July 13. The calmest day of the year is February 6, with an average hourly wind speed of 6.6 miles per hour [40].

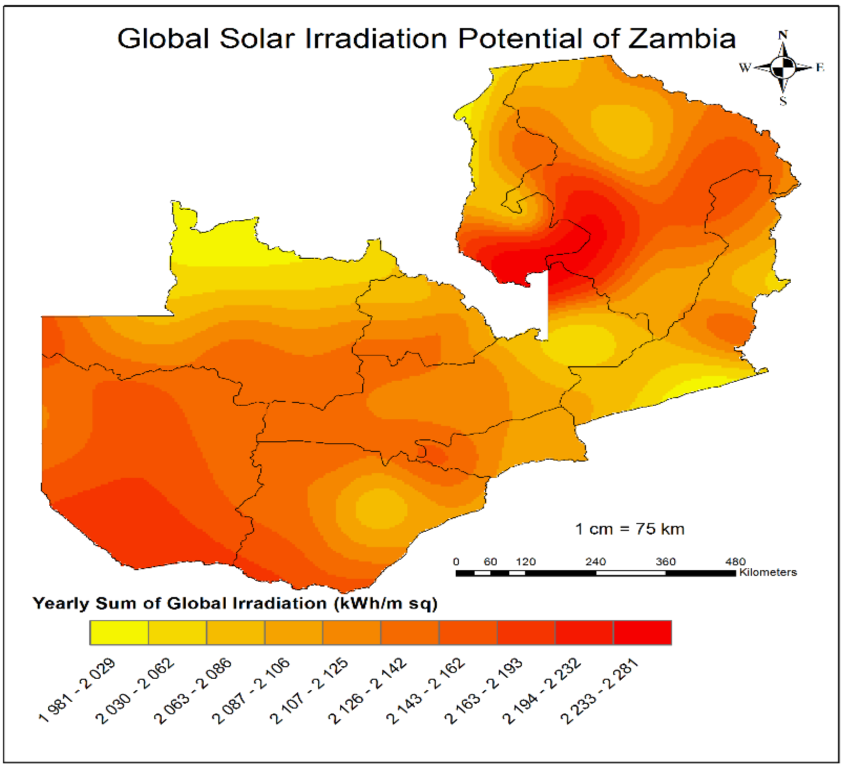

Fig. 7. Annual Total Global Solar Radiation Intensity
Source [36]

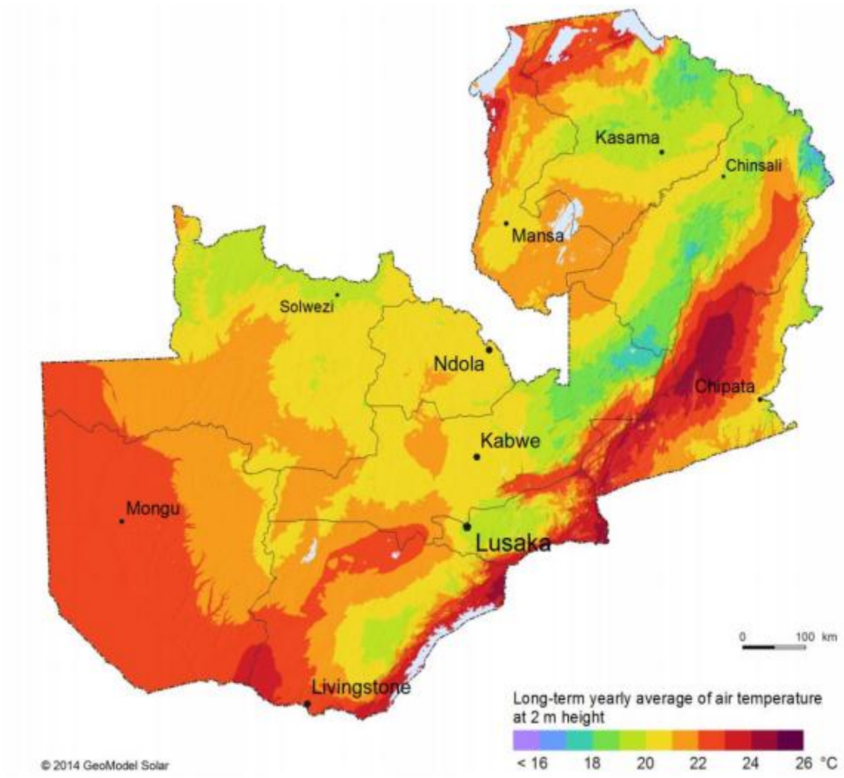

Fig. 8. Long term yearly average of air temperature at 2 meters
Source: CFSR

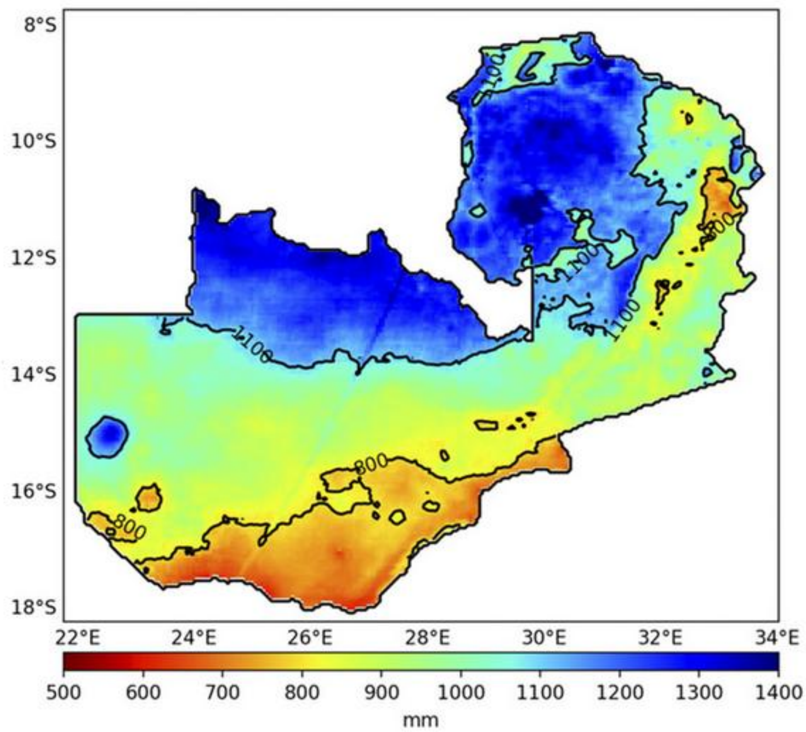

Fig. 9. Average annual rainfall map of Zambia, 2000-16, source: CHIRPS [40]

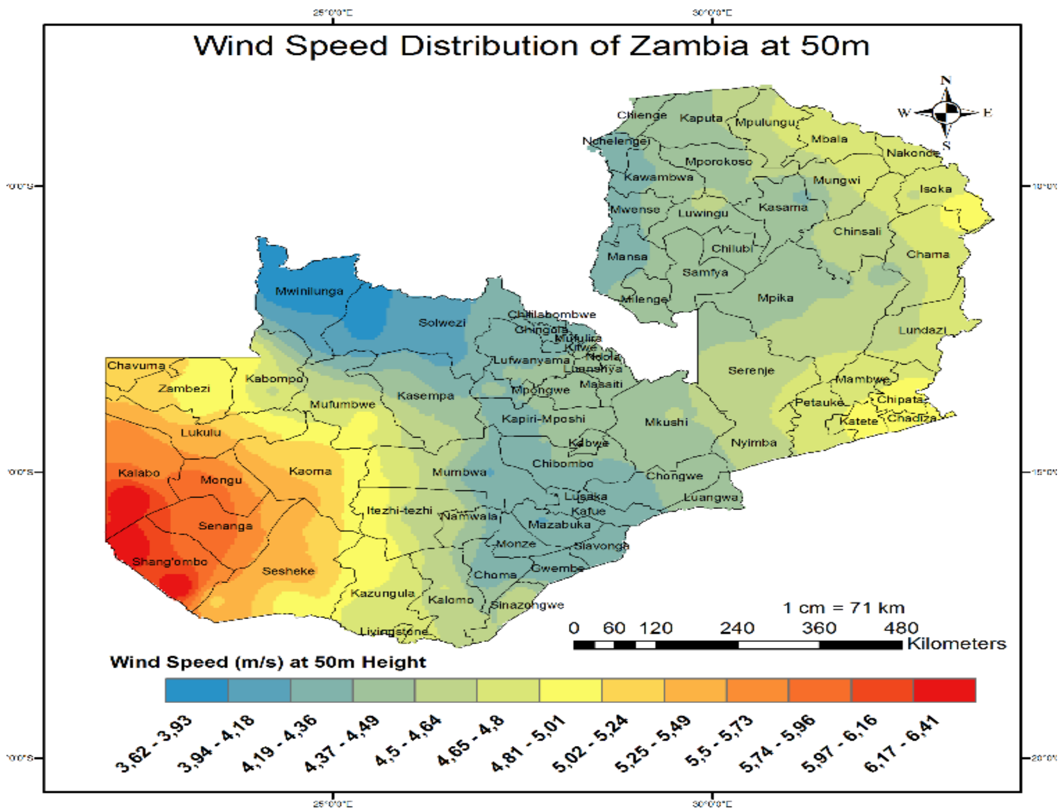

Fig. 10. Annual wind speed at 50m [41]

3. METHODOLOGY

3.1 Research Design and Approach

The goal of this project is Identifying and Analysing the Technical challenges of inverters for grid connected PV system due to different condition. Combines quantitative and qualitative approaches, mixed methods are used. This allows for the phenomenon that is being researched to be better understood. A detailed literature review is conducted which has direct or indirect relation on technical challenges of inverters for grid connected PV system due to different conditions. Different research has been done and is on-going. In each review, the contribution made, research not done and limitations has been documented. Some of the missing achievements are being investigated in this research.

On this study different site are selected we shall have a detailed view on the study area on section 3.2, from the horn of Africa Ethiopia and southern of Africa Zambia. In Ethiopia 8 site are selected (mini off-grid sight) and in Zambia two site are selected (on-grid sight). The researcher collects and analyses numerical data via a quantitative technique, such as a survey and qualitatively the researcher make an observation, formulate research questions, and conduct interviews. The following are the main research approach.

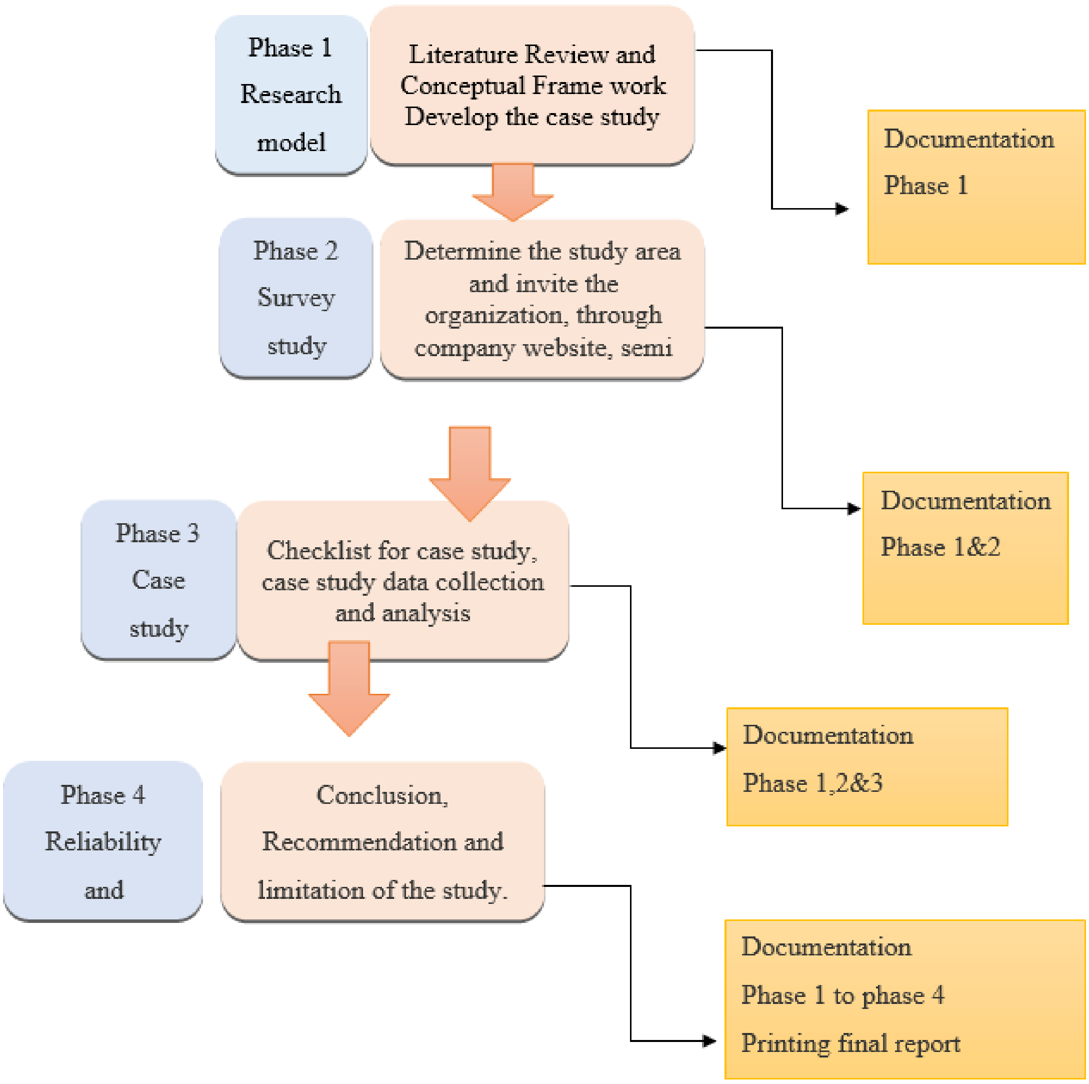

Fig. 11. Research frame work

3.2 Study Area in Zambia

The study basically based in Lusaka south multi-facility economic zone. There are two grid connected independent solar plant, the 54 megawatts Bangweulu solar power plant by Neon Investment of France and the 34MW *Ngonye solar* photovoltaic (PV) plant [42].

3.3 Study Area in Ethiopia

Ethiopia is a country on the Horn of Africa. The country lies completely within the tropical latitudes and is relatively compact, with similar north-south and east-west dimensions. The capital is Addis Ababa ("New Flower"), located almost at the centre of the country. Ethiopia is the largest and most populated country in the Horn of Africa [44].

In Ethiopia there are two government institutions which are working under supplying electricity. The first one is Ethiopian Electric power (EEP) and Ethiopian Electric Utility (EEU).

3.4 Data Collection Procedure

3.4.1 Primary data

Primary and Secondary sources of data used for data analysis. Primary data used to get empirical investigation. Thus, this study used physical observation and interviews in order to identify the problems in the existing site related to grid tide solar inverter.

Primary Data: Data that has been generated by the researcher himself/herself, surveys, interviews, Photographs which shows different grid tide inverters site, the questionnaire specially designed for understanding and solving the research problem at hand. Primary data are the main input to the researcher final conclusion and recommendation for farther investigation.

3.4.2 Secondary data

Secondary data are basically second-hand pieces of information. These are not gathered from the source as the primary data. To put it in other words, the secondary data are those that are already collected. Secondary sources that are not first-hand, i.e., that cannot be traced back to its source by directly linked. This data allows the researcher to visualize the type of problem faced by past researchers, regulation boards and the ministry. The following are the main source of secondary data collection mechanizer the researcher used.

3.4.3 Internet

The data got from the internet i.e., YouTube, Websites on different challenges of solar grid tide inverter by different organizations in the world, and written journals that cannot be obtained in physical form. But they are the easy to access and give a good start to the researcher based on the objective of the researcher.

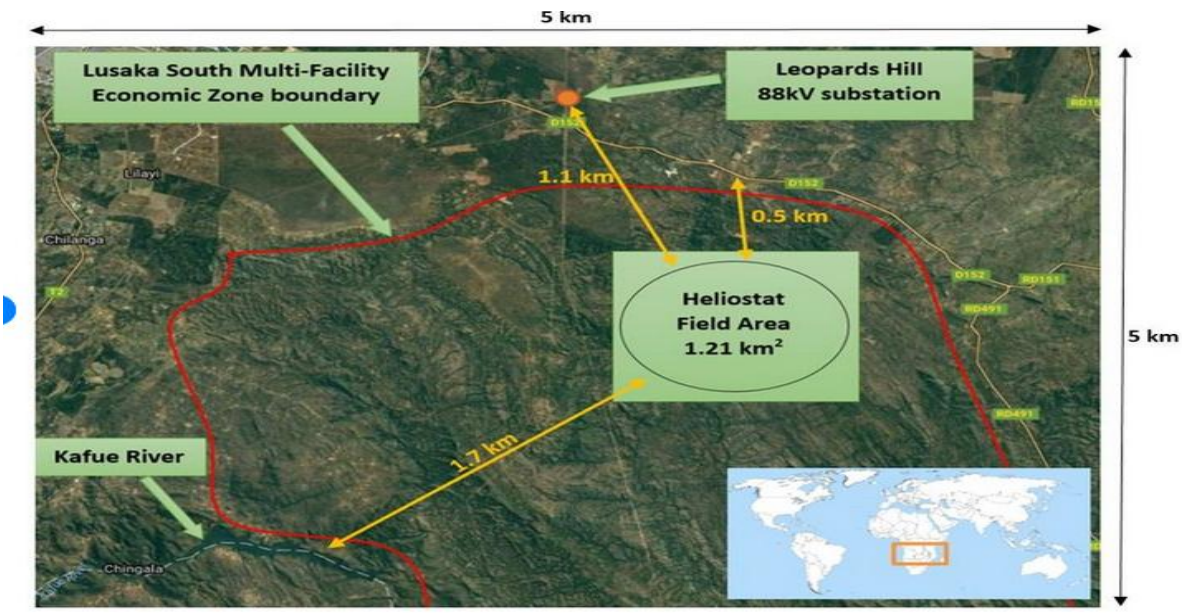

Fig. 12. Satellite view of Lusaka South Multi-Facility Economic Zone showing the total field area occupied by the plant and estimated distances from the river, [43]

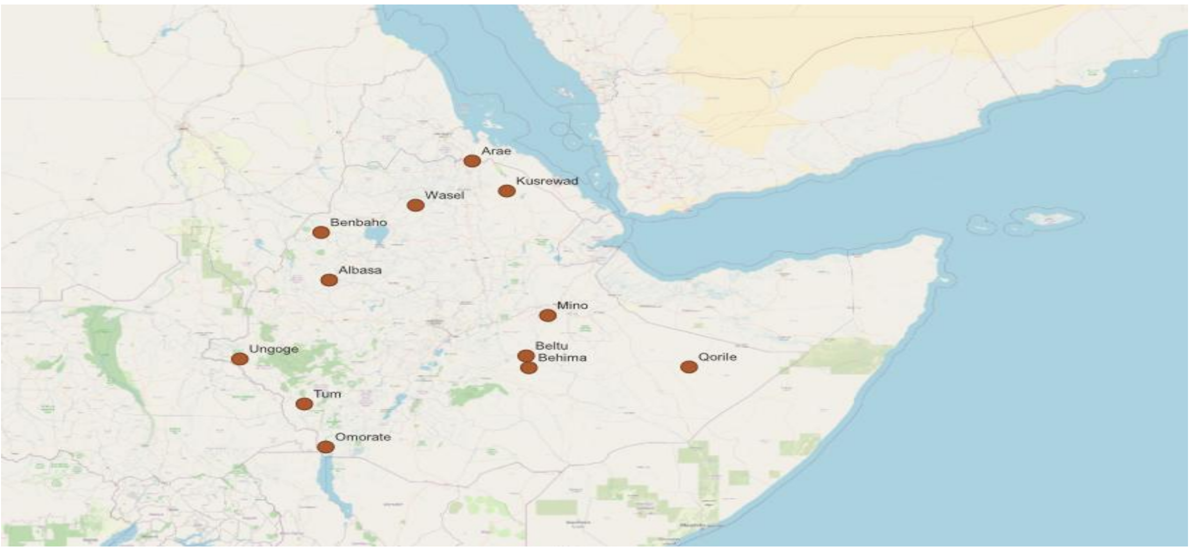

Fig. 13. Mini grid sites in Ethiopia

3.4.4 Journals and conference papers

These are important papers from academics who have walked that path before. They may not be directly linked to the area under study, but will give direction through the findings that were done, recommendations made and suggestions for further research.

3.4.5 Books and magazines

Many books are written on solar energy, solar energy efficiency related to inverter performance, smart grids micro-grids, mini on-grids / off -grid solar plant. The gestures written in the documents give direction to the work at hand. All the resources used on this research is indicated on the reference section.

3.5 Data Analysis

This will be the case study, collection and analysing data. The data is processed using Microsoft Excel. Each and every data collected from each site, Ethiopia 8 mini off-gride site and Zambia 2 on-grid solar plant are included.

Table 1. Name of the selected site in Ethiopia and Zambia with the site location and the type of inverter

	Selected min off- grid site in Ethiopia	Site location		Types of inverters	Completion/commission date
		latitude	Longitude		
1	Beltu	7.878	40.99	KELONG-grid tie	08.02.2021
2	Behima	7.48	41.058	KELONG-grid tie	04.03.2021
3	Mino	9.24412.048	41.526	NR-grid tie	09.08.2020
4	Ungoge	7.775	33.931	NR-grid tie	03.12.2020
5	Korhele	7.504	7.504	NR-grid tie	24.10.2020
6	Tum	6.255	35.522	GroWatt-grid tie	31.03.2020
7	Omorate	4.801	36.05	GroWatt-grid tie	23.02.2021
8	Kofetu	1.23456	9.87654	Homer	
	Name of on-grid site in Zambia				
1	Bangweulu solar power plant	15.5239	28.3906	Huawei - SUN 2000-42 KTL (string inverter)	11.03.2019
2	Ngonye solar photovoltaic	15.5239	28.3906	FIMER – Model: R15015 TL (central inverter)	29.04.2019

A. Based on the objective of the research to identify and investigate the main grid tied inverter challenges due to different scenario mainly environmental condition which is the operating environment of the inverter. a questionnaire and a Sime structure interview is conducted. Which is attached to Appendix: A and Appendix B. The participant is selected based on their profession experience on monitoring and operating the solar plant.
B. a detailed literature review is conducted on chapter two in both countries based on the ongoing solar project and also the upcoming grid tide solar plant and mini grid site. in Ethiopia the researcher focused on the mini grid sites as it is indicated on Table 1. also, in Zambia the two main grid connected site at malty facility zone is included.
C. investigate, compere and identify the environmental \climate condition of the two country Zambia and Ethiopia. Solar radiation, Air temperature, Rain falls and Wind Using Microsoft excel for each selected site annual solar radiation, air temperature, rain falls and wind is investigated and analysed for the selected site
D. The basic inverter challenges are investigated from the collected data and the problem is analysed based on the specific inverter data sheet. The data sheet of the inverter for each site under this study is attached on Appendix D
E. Finally, a conclusion is made on how an inverter technical performance (efficiency) affected due to the inverter challenges. based on the efficiency of the inverter directly affects the performance of Solar power plant.

The overall efficiency of the inverter = Conversion efficiency* Tracking efficiency

Conversion efficiency: Power conversion efficiency of the Constant in laboratory conditions
Tracking efficiency: The maximum power point tracking efficiency in a rapidly changing load condition.

3.6 Validity and Reliability

Validation is a point where the researcher measure or test how the result is valid by correlating with the expected result. On the other hand, Reliability is a stage which allows you to assess the degree of consistency in your results based on your data analysis. Reliability provides an answer to the question of how similar your results are after that the researcher will conclude and recommend what is needed for future study.

3.7 Ethical Considerations

Ethical clearance to conduct this study was obtained from the University of Zambia Research Ethics Committee (See Appendix C). All the participants in this study were clearly informed of the objectives of this research, given adequate time to consider their participation and a consent was signed in agreement to participate. Further, the participants were assured of confidentiality of all the information given and no names were recorded.

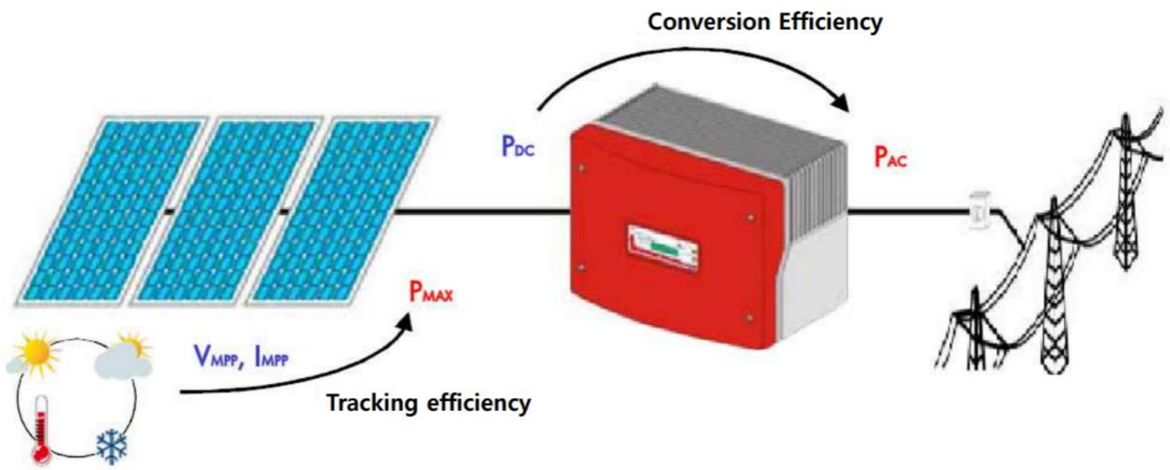

Fig. 14. Demonstrate the efficiency of the inverter

We conduct our investigation through the rubric of the affirmative and prohibitive principles for every company, to every individual and a group of people involved in this research paper. All the information and the data will not be abused and corrupted, in study it will be just for educational purpose. Grid connected photovoltaic system technology development has and continue to have different impacts in different social contexts, and by considering the different impacts/challenges grid tide inverter explicitly across global contexts due to different challenges like faulty installation, inverter beeping, the MPPT modules, Environmental condition and others related issues based on the geographical Environmental differences between Zambia and Ethiopia contexts, this paper contributes to identifying and understanding how, in what ways, and in what particular conditions and circumstances grid connected photovoltaic electricity technologies may correspond with or work to promote (electric power) energy justice.

4. RESULTS AND DISCUSSION

4.1 The Common Types of Inverters used in Grid Connected PV System in Ethiopia on the Selected site and the Climate Condition of the Area

In Ethiopia there are two government institutions which are working under supplying electricity. Ethiopian Electric power (EEP) and Ethiopian Electric Utility (EEU). Ethiopian Electric Power owns and operates the Ethiopian national power grid with all High voltage power transmission lines *above* 66 kVincluding all attached Electrical Substation and almost all power plants within the national power grid including the controversial Great Ethiopian renaissance dam (GERD) project which is Africa's largest hydroelectric project, with a capacity of 5,000 MW.

Currently we don't have fully function grid connected solar plant. The Metahara Solar PV power plant, which were planned to supply electricity to the Ethiopian national grid, is of the largest solar power facilities in Africa. The project location encompasses 250 hectares of undeveloped land adjacent to the main road between Addis Ababa and Djibouti. Due to multiple factors from regulation to tariff to currency made it impossible to implement the project. The memorandum of understanding was signed for a private developer to develop the plan and sell to the grid. The project was planned to have an Inverters which convert the DC current produced by PV modules to grid-exploitable AC current (three-phase 400V at utility frequency). They typically range from approximately 20 kVA (decentralized) up to 2,500 kVA (centralized inverters). Inverters are central components in the communication with the SCADA system, since they monitor the strings operation. PV inverters also have special functions like maximum power point tracking or anti-islanding protection. The preliminary design was including a total of 80 inverters.

On the other hand, The Ethiopian Electric utility (EEU) mini grid project, have 12 minis off grid solar power site. Out of this, 10 sites are energized before two years and fully functioning. For each site different contractor install the system so the type of inverter differs from site to site based on the contractor selection. The above map shows the site location for the mini grid solar power station in Ethiopia under Ethiopian Electric Utility (EEU).

Among the list of types of inverter NR-grid tie inverter are shown below from the site photo. It is also used in three sites Mino, Ungoge, and Korhele..

All sites are far away from the grid, as a backup they have diesel generator. Which serve only critical load and to recharge the battery. Under EEU there are also 25 sites under construction and also 201 mini grids sit to be implemented up to 2027.

On this paper we are going to see two mini off grid site in detailed among the Table 3.

4.1.1 Omorate model mini-grid site

Omorate is a town in southern Ethiopia near the Kenyan border. Located in the Debub Omo Zone of the Southern Nations, The MG was selected for the study owing to its location in a hot tropical climate, the availability of operational data and the fact that the MG is among the first PV power plants installed in Ethiopia. The town lies between 4° 80′ 16″N Latitude and 36°3′29″ E Longitude with an average elevation of 368 m.a.s.l. The mean annual temperature in Omorate is 28.2°C.

The MG in Omorate has a total installed capacity/rated power of 375 kWp. The PV array consists of 1210 series-connected monocrystalline PV modules from Jinko (Model:

JKM310M-60). Each PV module has a rated power of 310 Wp and a rated efficiency of 18.94 %. The modules are assembled into 9 strings in two parallel rows. Each string is connected to one inverter from Growatt*(Model: MAX 50KTL3 LV)* that has a maximum output power of 50 kWp. Each inverter has 6 maximum power point trackers (MPPT).

The main system components of the MG include: PV modules, converters (solar direct current (DC) to alternating current (AC) inverters, and battery DC/AC inverters), battery energy storage system (BESS), MG monitoring and energy management system (MMEMS), a diesel generator (DG), a distribution panel (with three AC power feeders) and loads.

All the modules in each string are fixed on ground-mounted racks and positioned in a direction facing towards south at a tilt angle of 15°. The MG system is alternating current (AC)-coupled and is equipped with five Lithium Iron Phosphate (LiFePO4) battery packs with a total rated storage capacity of 600kWh.

Table 2. List of mini grids sites in Ethiopia which is shown on the above map

	Name min grid site	Types of inverters	Capacity	Number of inverters	Total expected output power
1	Beltu	KELONG-grid tie	60kw	14	750kw
2	Behima	KELONG-grid tie	60kw	4	204.6kw
3	Mino	NR-grid tie	33kw	7	225.1kw
4	Ungoge	NR-grid tie	33kw	6	175Kw
5	Korhele	NR-grid tie	33kw	10	325Kw
6	Tum	GroWatt-grid tie	50kw	11	550kw
7	Omorate	GroWatt-grid tie	50kw	8	375kw
8	Kofetu	Homer	100kw	2	200kw

Table 3. List of mini grid sites in Ethiopia; energy produced in KWH; 2021

No	Name mini grid site	Month	Energy in KWH
1	Tum	March	199,152,00
		April	219,012.00
		May	238,570.00
		June	258,462.00
2	Uguge	March	110,119.00
		April	118,671.00
		May	127,945.00
		June	135,902.00
3	Behima	March	64,587.00
		April	70,557.00
		May	74,758.00
		June	80,211.00
4	Mimo	March	98,748.00
		April	106,885.00
		May	114,876.00
		June	122,666.00
5	Omorate	March	395,690.00
		April	435,768.00
		May	462,273.00
6	Beltu	March	381, 560.00
		April	422,800.00
		May	669,912.00
		June	519,376.00

Fig. 15. NR-grid tide inverter rating 33kw

Fig. 16. A view of the PV MG infrastructure in Omorate, Dasanech district, Southern Ethiopia

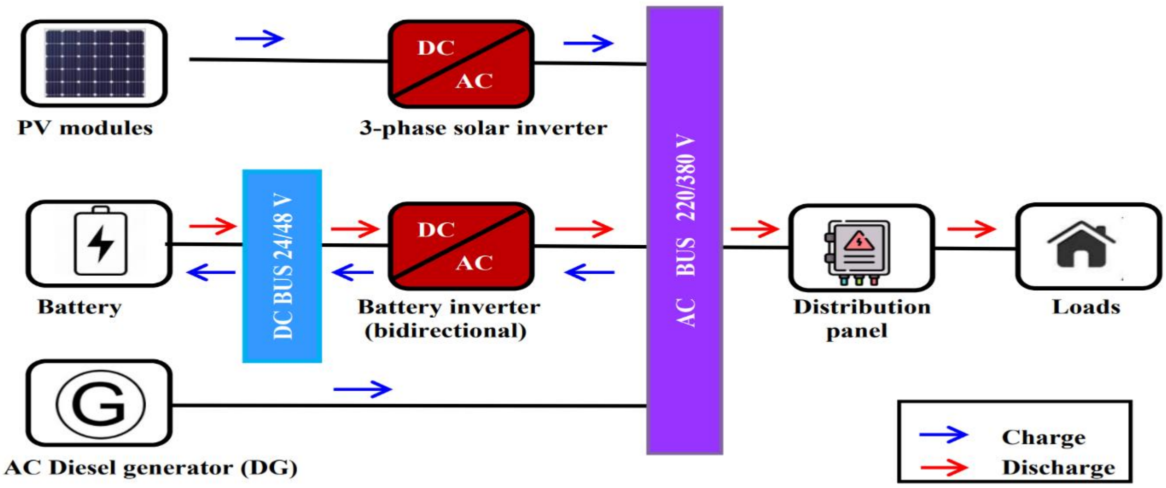

Fig. 17. Solar plant schematic diagram for omorate mini off-grid site

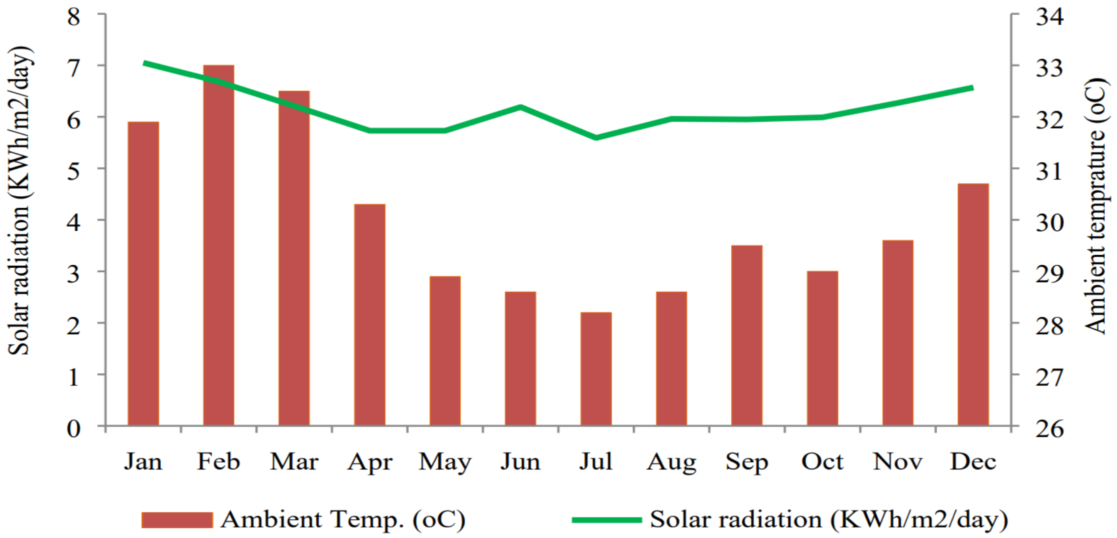

Fig. 18. Solar radiation and Ambient temperature of Omorate, Dasanech district, Southern Ethiopia

4.1.2 The environmental condition of the area: Omorate, Dasanech district, Southern Ethiopia

According to the measured solar irradiation data, the total annual solar energy resource incident on the tilted PV array is 2247 kWh/m2 /year. The average daily solar irradiation is 6.1 kWh/m2 , however, it varies between 4.6 and 7.5 kWh/m2 /day. The monthly average daily solar irradiation and ambient temperature. The figure displays that the lowest average daily solar irradiation (5.59 kWh/m2 /day) is recorded in July. The peak irradiation (7.05 kWh/m2 /day) is recorded in January. The average daily ambient air temperature at the MG site is 30.1 °C, with a minimum of 28.2 °C in July and a maximum of 33.0 °C in February. In general, Fig. 18 shows that the distribution of solar irradiation at the MG site has little seasonal variation.

4.1.3 Kofute model mini-grid site

The plant site Koftu, located 40km South West from the Capital City of Addis Ababa.The project is built as a model project by the support of South Korea from KIAT (Korea Institute for Advancement of Technology) given to EEU and was completed 2019. The Project implementation unit was – EEU, UEAP (Universal Electric Access Project).

The solar mini grid site can supply 327 house holed by satisfying the power demand 100kw of load power and 151 kw of work load with eco-friendly energy. The selected panel is 320w there for the total panel required for 250kw is 630 panel. The optimum design is made by homer. The following shows the schematic diagram of the system in koftu.

As we can see from the schematic there are two sites in koftu site “A ’The AC/DC conversion unit PCS (power conversion unit) is 100kw each. Both they are bi lateral and connected to the battery. On the other side site “B” is operating inverter 50kw bi lateral PCS directly connected to the battery and the solar panel. The backup diesel generator is rating 30kw.

4.1.4 The environmental condition of the area: Koftu South West from the Capital City of Addis Ababa

The solar radiation of the site is 5.81kw/sqm/d, the panel inclination is 5^0 the solar

4.2 The Common Types of Inverters used in Grid Connected PV System in Zambia on the Selected Site and the Climate Condition of the Area

In Zambia there are few national grids connected plant among the few on this study will try to investigate two independent grid connected solar plant in multi facility zone, the 54 megawatts Bangweulu solar power plant by Neon Investment of France and the 34MW Ngonye solar photovoltaic (PV) plant by Enel Green power investments.

Fig. 19. Geographical location of Koftu

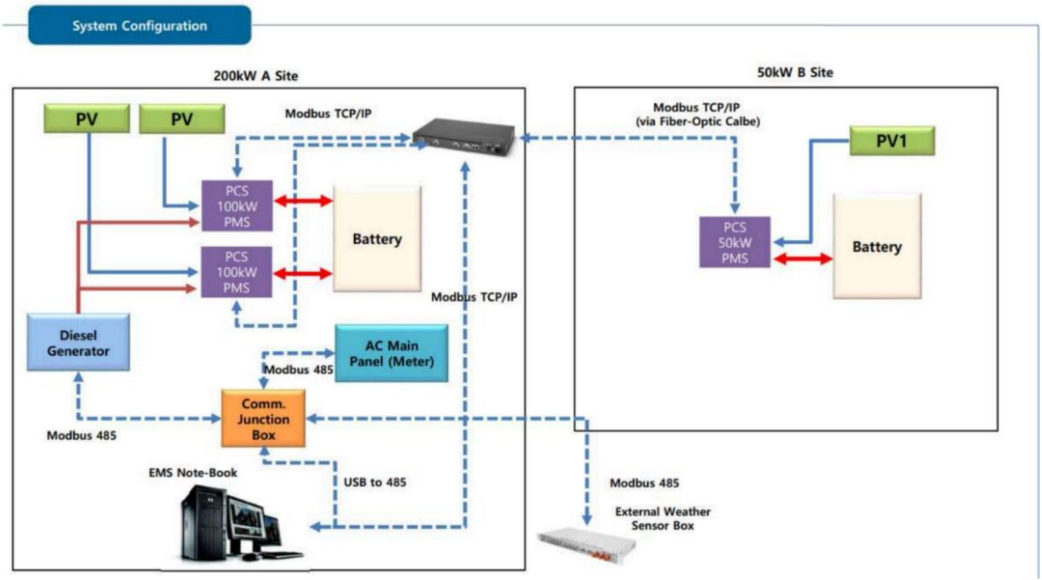

Fig. 20. The schematic diagram of koftu solar power site

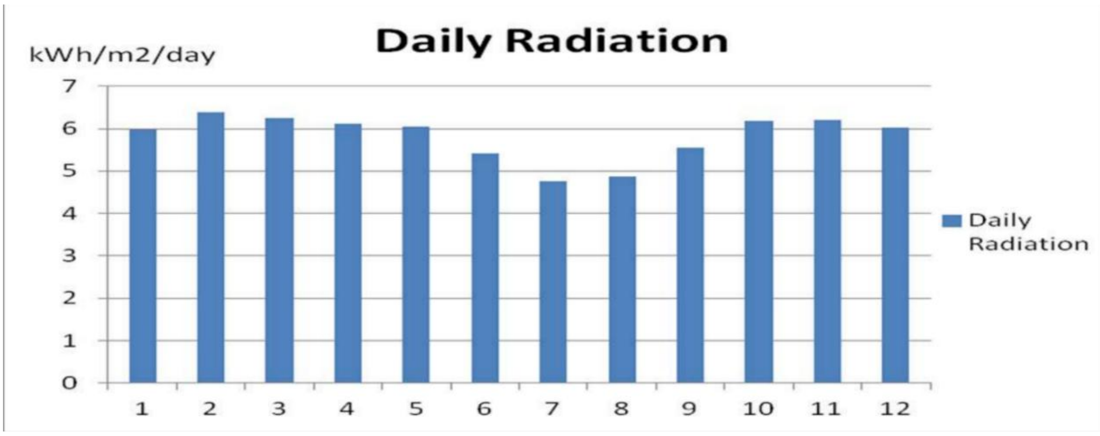

Fig. 21. Daily radiation curve KWh/m^2 of Koftu

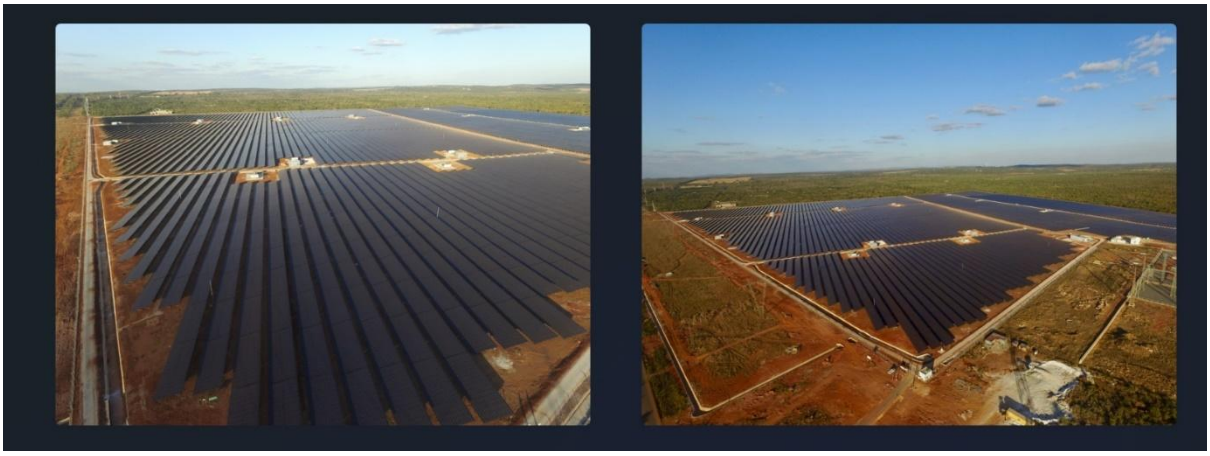

Fig. 22. The Bangweulu solar power plant at multi facility center

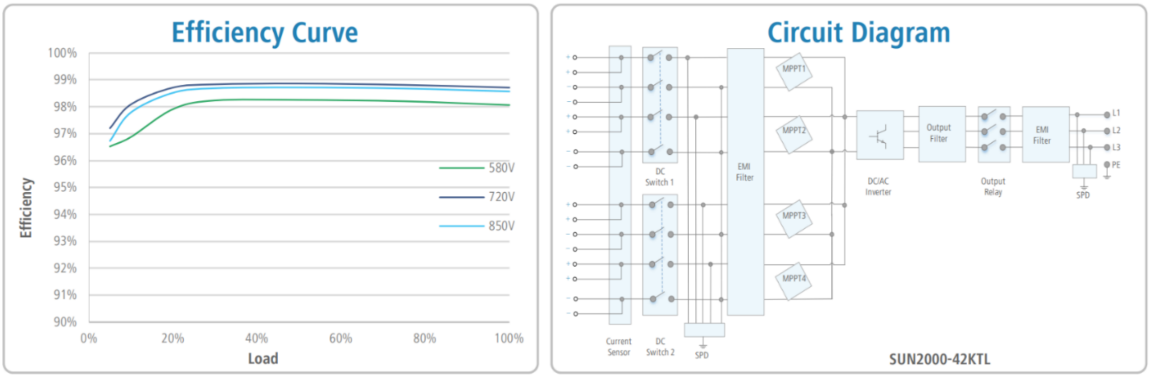

Fig. 23. Smart String Inverter SUN2000-42KTL circuit diagram and efficiency curve

Fig. 24. Huawei - 480-volt Inverter from Bangweulu solar power station

4.2.1 Bangweulu Solar Power Station (BSPS)

Bangweulu Solar Power Station (BSPS), is a 54 MW (72,000 hp) solar power plant in Zambia. The solar farm that was commercially commissioned in March 2019 was developed and is owned by a consortium comprising, Neoen a French IPP, Industrial Development Corporation of Zambia (IDC Zambia).

The Bangweulu solar power plant has been producing 54 MW solar power and feed to the national grid ZESCO, for three years since 2018 up to now. There are 12 blocks; each block is accompanied by 33kv step up transformer, circuit braker (sf6-gus insulated circuit breaker). There are a total of 1230 string inverter each produced 480 volt which is 42 KW power. The inverter has a capacity to receive DC power from 2000v to 1000v (Huawei - SUN 2000-42 KTL).

4.2.2 Ngonye Solar Power Station (NSPS)

Ngonye Solar Power Station (NSPS), is a 34 MW (46,000 hp) solar power plant in Zambia. The solar farm that was commercially commissioned in April 2019 was developed and is owned by a consortium comprising Enel Green Power of Italy, a multinational renewable energy corporation, and the Industrial Development Corporation of Zambia (IDC).

Ngonyesolar plant, in the Lusaka South Multi Facility Economic Zone, is using tracking systems that feature solar photovoltaic (PV) panels to track the movement of the sun throughout the day, capturing sunlight and converting the energy into electricity. There are a total of 24 grid connected central PV inverter each produced550 volt which is 1410 KW power. The inverter has a capacity to receive DC power from 1320v to 850v (FIMER – Model: R15015 TL).

The tracking of the sun is achieved using a global positioning system (GPS) connected to an electronic tracker control board (ETCB). The integrated GPS device acquires both date and time. Each single-axis tracker automatically tracks the sun's East to West movement during the day. A single ETCB controls a maximum of ten structures with a PV energy capacity of about 97.5 kW. The primary benefit of the tracking system is that it improves plant efficiency by increasing energy output as it lengthens the plant’s peak generation period above similar-sized fixed axis plants.

4.2.3 Environmental Condition of Ngonye solar power station (NSPS) and Bangweulu solar pant station (BSPS)

Both power plants they are found on the same area at multi facility zone Lusaka Zambia they are experiencing the same environmental condition even though they are managed by different company. with different types of inverters and different set up. From the interview which is conducted and the data which is collected.

The climate of the area is characterized by three distinct seasons: cool dry season from mid-April to August; hot and dry season from September to October; a rainy season from November to April.

The area receives annual rainfall in the region of 500 mm to 1000 mm with the mean annual rainfall being in the order of 800 mm. Moderate temperatures with mean monthly temperatures ranging between about 15^0c in the cold season to about 30^0 c in the hot season are experienced in the area. Prevailing easterly winds dominate the area during the dry season with fresh winds experienced in the months of July and August. Mean wind speed recorded in the area ranges from 4 km/hour to 9 km/hour. Extreme wind events in the area are associated with thunderstorms and transient, short-term “dust devils” and may reach 112 km/h. Sunlight hours per day range from 5 hours to 9 hours in August with an annual average of 7 hours per day.

Fig. 25. Ngonye solar plants, in the Lusaka south multi facility economic zone

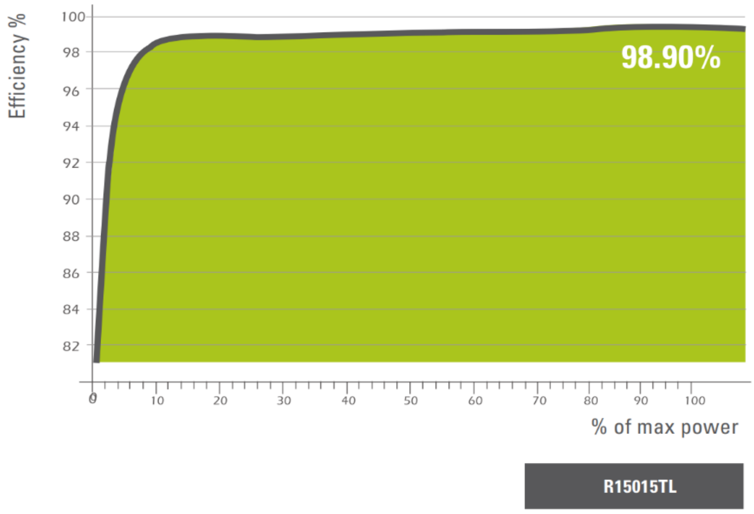

Fig. 26. Efficiency curve FIMER – Model: R15015 TLcentral inverter

The Table 4 displays max and min temperature and rain data for the whole year as an average taken from last 12+ years of historical data for Kafue. (Multi facility zone Lusaka Zambia)

4.3 Technical Performances Challenges of Grid Tide Inverter

From the survey collected data in Ethiopia and Zambia at the selected site. The following are the main grid tide solar inverters technical performance challenges.

4.3.1 Weather condition

The weather change which we experience every day it affects the solar plant specially temperature is one of the basic issues which Couse inverter component fail. Operating temperature affect the inverter performance directly. From the interview I conducted in both region Ethiopia on the selected mini grid site and Zambia on Ngonye and Bangweulu, whether affect the solar plant in both sides.

Addis Ababa generally has cooler weather than Lusaka. The average mean temperature in Addis Ababa is 17.24°C (63.03°F) while Lusaka's temperature is 22.87°C (73.17°F) and the difference is 5.63°C (42.13°F). Addis Ababa is warmest on average in April, when the day time temperature may reach 18.89°C (66.0°F), while Lusaka is hottest in October when the average high temperature is 28.17°C (82.71°F). Addis Ababa is coldest in December when the average low temperature is 7.56°C (45.61°F), while July is the coolest month in Lusaka, when night time temperature often falls below 10.51°C (50.92°F).

Finally, Addis Ababa has about 1.32 times more rainfall than Lusaka, (Addis Ababa's 79.54mm vs Lusaka's average of 60.34mm).

Table 4. Average annual temperature (^{o}C) of day, night and rain day

Month	Day	Night	Rain day
January	26	18	20
February	26	18	19
March	26	17	14
April	26	16	3
May	26	13	0
June	24	11	0
July	24	11	0
August	28	14	0
September	32	17	0
October	34	20	1
November	32	20	7
December	29	19	17

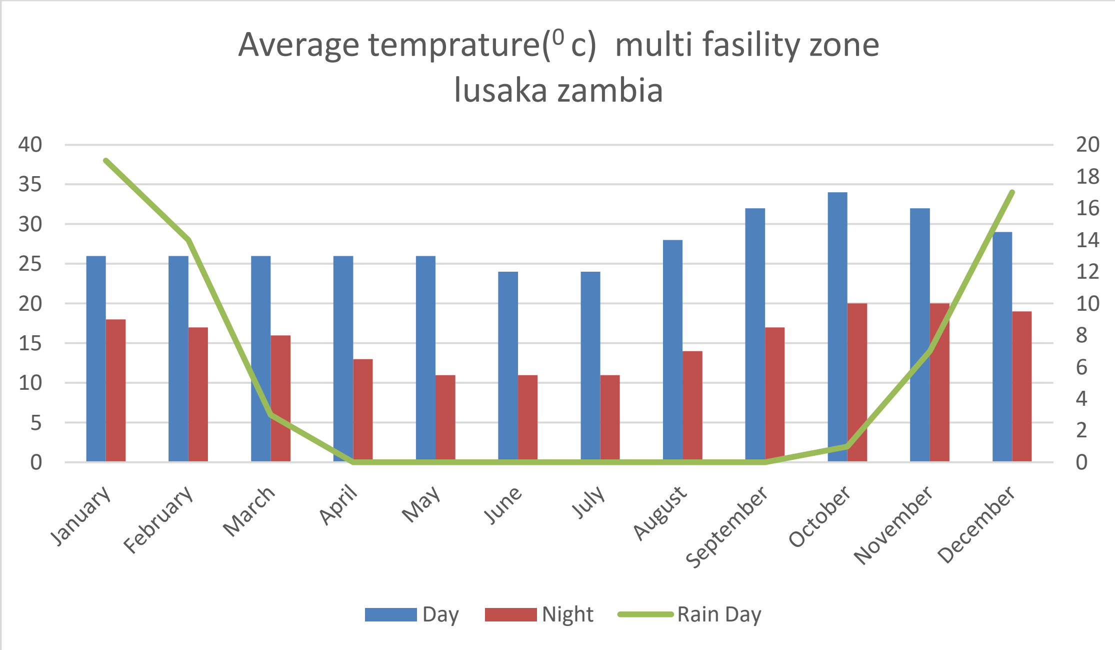

Fig. 27. Average temperature day, night and number of rain days

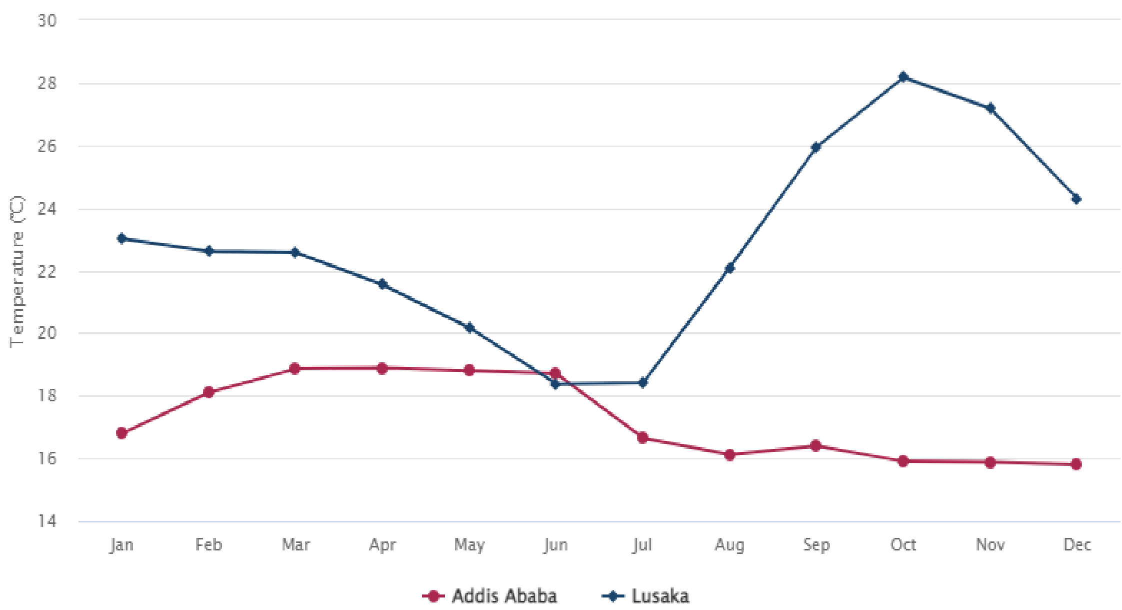

Fig. 28. compere the average annual temperature Addis Ababa the capital city of Ethiopia and Lusaka the capital city of Zambia [44]

4.3.1.1 The Effect of Temperature Rises on the ambient Temperature of the Inverter

As the inverter works to convert DC power to AC power, it generates heat. This heat is added to the ambient temperature of the inverter enclosure, and the inverter dissipates the heat through fans and / or heat sinks. The heat needs to stay below a certain level at which the materials in the inverter will start to degrade. In order to keep the heat low, the inverter will stop generating power or reduce the amount of power it generates by "derating" as it passes programmed temperature milestones. Most inverters will derate at around 45 – 50 Degrees Celsius.

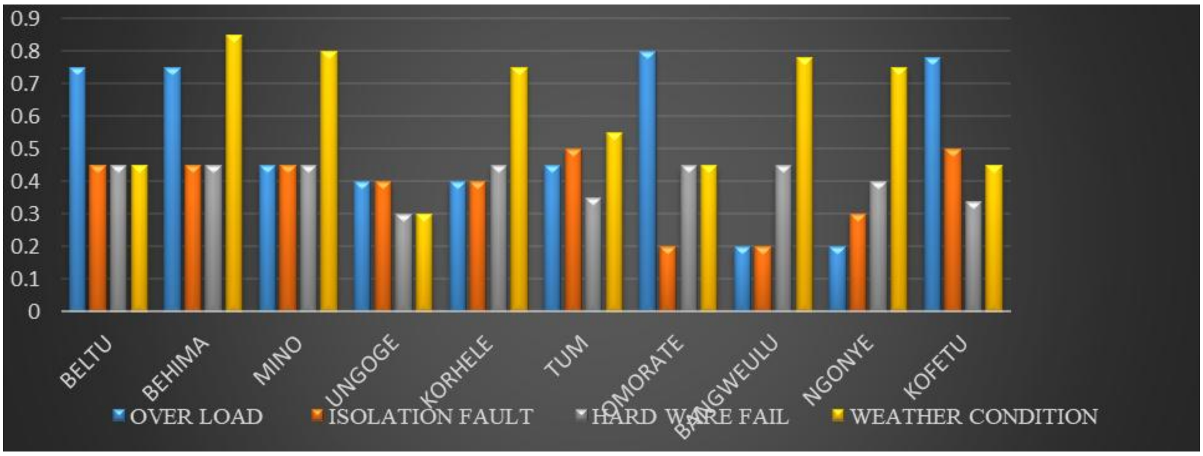

Fig. 29. Inverter Main Challenges analyzed from the collected data: Over load, isolation fault, hard ware fail and weather condition are the main challenges collected

As the ambient temperature increases the switching transistors are the elements which mostly suffer from the increasing the ambient temperature. As the ambient temperatures increases the rate of heat flow from the transistor to the ambient decreases. There is a derating factor of the allowed power dissipated in the device as the environmental temperature increases. This power derating curve is given in the data sheet of the power transistors.

4.3.2 Inverter operating mode and fault detection

The inverter will be set to the appropriate model according to the standard of different country or region before it is leaving the factory. For example, the inverters shipped to Australia are configured as Australian model in the factory. Note: The inverter is configured for Australia at the factory.

Inverter intelligent control system will continuously monitor and adjust system status. When there is a fault detected, LED will show the fault message. All inverter they have an operational manual base on their model number.

The following is modes of inverter operation. The information is taken by from the inverter operating manual. Every inverter has their own application software. The operator can able to see how the inverters are preforming.

4.3.2.1 Working modes

At this mode, inverter work normally, and the shows the power delivered by the inverter to the grid. When the DC voltage is more than the rated Vdc from the data sheet, inverter converts the DC power generated by the PV modules into AC power and supplies them to the grid. When the DC voltage is lower than the minimum range Vdc, inverter will enter into “waiting” state and try to connect to the grid, at this status, inverter consume very small power to check the internal system status. Note: only when the PV modules supply enough power (voltage＞ minimum Vdc) then the inverter will start automatically.

4.3.2.2 Off modes

When the sunlight is weak or no light, inverter will stop working automatically. When it is off, inverter will not consume gird power or PV module. At the same time, the LED of inverter will be turned off.

4.3.2.3 Fault modes

Inverter intelligent control system will continuously monitor and adjust system status. When there is a fault detected, LED will show the fault message.

The following are some of the faults registered from the selected site in relation the inverter performance.

A. Hard were fail: The most common cause of failure or malfunctioning for inverters is an improper installation, often a combination of not following the user manual recommendation and selecting inappropriate cable type, gauges or in line fuses.

In Ethiopia among the Mimi grids which is in stole and currently operating. Belt of Southern Ethiopia which is one of the mini grid sites the inverter experienced a hard were failed on November 11 2022, and the engineers are investigating the cases. The inverter type is KELONG rating 60 Kw. According the information collected from the site the hard ware fail can be due to excessive water under the inverter due to heavy rain on the area.

B. Over load: The most common reason for a power overload is when the inverter is used to its hilt or instead reaches its peak power output. You may argue here that industrial power inverters can withstand as much as twice its peak power. However, there is always the possibility of your connecting too much equipment to the inverter.

Omorate (also known as Kelem) is a town in southern Ethiopia near the Kenyan border. Located in the Debub Omo Zone of the Southern Nations, Nationalities and Peoples' Region, this village has a latitude and longitude of 4°48′N 35°58′ECoordinates: 4°48′N 35°58′E with an elevation of 395 meters above sea level. It is the administrative center of Kuraz woreda.

In Omorate site have a mini grid solar powered station, the total capacity of the station is 550kw the inverter which is named Grow watt grid tide inverter rating 50Kw got an over loaded fault. Among other type of inverter fault over load is one of the frequent one.

C. PV isolation fault: In photovoltaic systems with a transformer-less inverter, the DC is isolated from ground. Modules with defective module isolation, unshielded wires, defective power optimizers, or an inverter internal fault can cause DC current leakage to ground (PE – protective earth). Such a fault is also called an isolation fault. [45] in Tum site most of the inverter fail due to PV isolation fault as the site engineer explained, they noticed that three inverters have got this problem due to water under the ground. For Kofetu site they experience some kind of fault the site technician are also investigating what makes the total inverter circuit to be burnt. The following photo shows tum site which is one of the 12 minis off grid solar power site.

D. Failure of Electronic component: Equipment, even electronics, has a higher likelihood of failure at the end of its life; electronics also have a significant failure rate at the beginning of service. One of the causes of failure of the equipment in solar plant is Over temperature which affects the solar panels as well as components in the inverter. Based on the data collected from the site, the component which experience significant failure are the IGBTs (insulated get bipolar transistor) have high rate of fail.

The following graph shows the overall inverter challenges analyzed from the data collected from different site mentioned above.

5. CONCLUSION

From the data collected and analysed the researcher comes up the following conclusions. All the data is collected and the information are analysed based on the real time situation of the plant. The researcher had a big challenge to retrieve the real time data from solar plant monitoring system. But Based on the questionnaire and sim- structured interview from the plant operator and Engineers this are the conclusi which is made.

The real-time performance of the inverter of the off-grid PV mini-grid system installed in a small remote town in Ethiopia and on-grid PV system from Zambia at multi facility zone is analysed using measured meteorological data.

From on- grid and off-grid inverter performance challenges, which the researcher collected from different plant the main ones are climate or environmental effect and also over load. Overload is one of the frequent challenges in koftu, behama and amorita this can be due to high population growth and unexpected power demand from the community.

Environmental condition affects almost all solar plant site which is under this study. If we compere the climate of east which is Addis Ababa Ethiopia and southern of Africa Zambia Lusaka. The temperature of Lusaka is higher than Addis Ababa by 5.63°C and even in the plant under this study, temperature rise is one of the challenges on the inverter performance, sensitive electronic component bent due to excessive temperature.

On the other side in Ethiopia Addis Ababa excessive rain affect the inverter. Addis Ababa has about 1.32 times more rainfall than Lusaka, (Addis Ababa's 79.54mm vs Lusaka's average of 60.34mm). for that reason, most of the inverter in Ethiopia on the mini off-grid site are affected by heavy rain condition. Most of the time the inverter is installed under the panel so when there is an excessive rain water cumulates under the panel and affect the inverter performance it can even burn the whole inverter that is what happened in one of plant in Ethiopia.

CONSENT

Written informed consent was obtained from approved parties for publication of this report and accompanying images.

ETHICAL APPROVAL

Ethical clearance to conduct this study was obtained from the University of Zambia Research Ethics Committee.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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APPENDICES

Appendix A: Data Collection Questions

Questioner

Date…………………………

Company name …………………………..

Position in the company …………….

Education background ……………………….

1. What kind of inverter are you using? And its capacity? ……………………
   ……………………………………………………………………………………………
   ……
2. Wha are the basic challenges of your solar plant in related to inverter performance in general, explain briefly? …………
   ……………………………….
3. From the following list of challenges of the inverter which one of the following affects the solar plant expected power output? Please indicate as shown below.

Challenges of the inverter	frequently	Sometimes	Not at all
a. Faulty installation of the inverter			
b. Overheating			
c. Isolation fault			
d. The MPPT models			
e. Climate condition			

Appendix B: Semi-Structured Interview Guide

Solar plant operators

Introduction

Thank you for participating in this interview. We are interviewing you to better understand how the inverter is working on delivering the expected solar power output. So, there are no right or wrong answers to any of our questions, we are interested in your own experiences.

Participation in this study is voluntary and your decision to participate, or not participate, will not affect the care you currently receive from the University of Zambia. The interview should take approximately one hour depending on how much information you would like to share. With your permission, I would like to audio record the interview because I don't want to miss any of your comments. All responses will be kept confidential. This means that your interview responses will only be shared with research team members and we will ensure that any information we include in our report does not identify you as the respondent. You may decline to answer any question or stop the interview at any time and for any reason. Are there any questions about what I have just explained?

Establishing Rapport

Before we begin, it would be nice if you could tell me a little bit about yourself. Tailor question here to specific person and/or situation. For example "how long have you been working in the company?"

1. Information about the solar plant, faults in solar plant and its courses
- When did the solar plant start functioning? Have you ever come across any faults? Pleases explain on this matter.
2. Inverter types and capacity
   Can you tell me about the type of inverter the company uses?
- How much is the capacity in KV and how do you connect it with the solar panel? Is it a string or central connection or any other?
3. Inverters challenges
- In general, what are the basic challenges of the inverters? Can you explain? How is the inverter interaction in different environments condition?

Appendix C: Data sheet of the inverter for the solar plant sit, which is under this study

Bangweulu solar power plant inverter data sheet

Smart String Inverter (SUN2000-42KTL)

HUAWEI

Technical Specifications	SUN2000-42KTL
	Efficiency
Max. Efficiency	98.8%
European Efficiency	98.6%
	Input
Max. Input Voltage	1,100 V
Max. Current per MPPT	22 A
Max. Short Circuit Current per MPPT	30 A
Start Voltage	250 V
MPPT Operating Voltage Range	200 V ~ 1,000 V
Rated Input Voltage	720 V
Number of Inputs	8
Number of MPP Trackers	4
	Output
Rated AC Active Power	42,000 W
Max. AC Apparent Power	47,000 VA
Max. AC Active Power (cosϕ=1)	Default 47,000 W; 42,000 W optional in settings
Rated Output Voltage	480 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Rated Output Current	50.6 A
Max. Output Current	56.6 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Max. Total Harmonic Distortion	< 3%
	Protection
Input-side Disconnection Device	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Monitoring Unit	Yes
	Communication
Display	LED Indicators, Bluetooth + APP
RS485	Yes
USB	Yes
Power Line Communication (PLC)	Yes
	General
Dimensions (W x H x D)	930 × 550 × 283 mm (36.6 x 21.7 x 11.1 inch)
Weight (with mounting plate)	62 kg (136.7 lb.)
Operating Temperature Range	-25°C ~ 60°C (-13°F ~ 140°F)
Cooling Method	Natural Convection
Max. Operating Altitude	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
DC Connector	Amphenol Helios H4
AC Connector	Waterproof PG Terminal + OT Connector
Protection Degree	IP65
Topology	Transformerless
	Standard Compliance *(more available upon request)*
Certificate	EN 62109-1/-2, IEC 62109-1/-2, IEC 62116, IEC 60068, IEC 61683
Grid Code	IEC 61727, AS/NZS 4777.2, G59/3, PEA, MEA, Resolution No.7

Ngonye solar power plant FIMER– Model: R15015 TL central inverter data sheet

DC Input - PV Module	R12015 TL	R13515 TL	R15015 TL
Nr Modules	8	9	10
MPPT voltage range(V_{DC})		850 - 1.320 V	
Max no-load PV voltage (V_{OC})		**1.500 V**	
DC-voltage ripple (%)		>2%	
Maximum input current (A_{DC})		1.600 A	
DC control mode		Rapid and efficient MPPT control	
Number of MPPT		1	
Reverse polarity protection		•	
DC input connection		DC Switch under load	
Overvoltage protection		SPD device Class I+II	
Reverse Polarity Protection		•	

AC Output grid

Nominal power (kVA)* (Note1)	1.128 kVA	1.269 kVA	1.410 kVA
Max current (A_{AC})	1.184 A	1.332 A	1.480 A
Max unbalance current		< 2%	
AC output Voltage (V_{AC})		$550V_{RMS}$ ±10%	
Nr Phase		3-phase (L1-L2-L3-PE)	
Frequency (Hz)		50/60 Hz	
Aux. power supply (V_{AC} - I_{AC})		230V ±10% - 16A (L-N)	
Auxiliary control supply		230V ±10% - 10A (L-N)	
Distortion factor (THD)		< 3%	
Galvanic insulation		No (transformerless)	
AC input connection		Magnetothermic AC grid switch	

General Data

Maximum efficiency		98.90%	
European efficiency		98.62%	
Static MPPT efficiency		> 99.9 %	
Dynamic MPPT efficiency		> 99.8 %	
Night consumption (W)		< 60 W	
Maximum power dissipated in overload condition	34,0 kW - 29250 Kcal/h	38,0 kW - 32675 Kcal/h	42,0 kW - 36113 Kcal/h
Weight (kg)	1.400 kg	1.500 kg	1.600 kg
Protection degree		IP20	
Cooling		Air forced cooling fan speed controlled	
Dimensions (WxDxH mm)		1.996x825x2.235 mm	
Noise level (dBA)		< 70 dBA	
Operating temperature (°C) *(Note3)		-10° C +53° C	
Storage temperature (°C)		-20° C +60° C	
Humidity Not condensing		0 ÷ 95%	
Height above the sea (without derating) *(Note 2)		1.500 m	
Air Flow	4.000 m^3/h	4.400 m^3/h	4.800 m^3/h
Protection class		II	
Colour		RAL 9006	

Tum and Omorate solar power site 60 KW Grow watt inverter data sheet

Datasheet	MAX 50KTL3 LV	MAX 60KTL3 LV	MAX 70KTL3 LV	MAX 80KTL3 LV
Input Data				
Max.DC power	65000W	78000W	91000W	104000W
Max.DC voltage	1100V	1100V	1100V	1100V
Start Voltage	250V	250V	250V	250V
MPP work voltage range	200V-1000V	200V-1000V	200V-1000V	200V-1000V
Nominal voltage	585V	585V	600V	685V
Max. input current per MPPT	25A	25A	25A	25A
Number of MPP trackers / strings per MPP tracker	6/2	6/2	6/2	6/2
Output (AC)				
Rated AC output power	50000W	60000W	70000W	80000W
Max. AC apparent power	55500VA	66600VA	77700VA	88800VA
Max. output current	80.5A	96.6A	112.7A	128.8A
AC nominal voltage	230V/400V;340-440V	230V/400V;340-440V	230V/400V;340-440V	230V/400V;340-440V
AC grid frequency	50Hz/60Hz,±5Hz	50Hz/60Hz,±5Hz	50Hz/60Hz,±5Hz	50Hz/60Hz,±5Hz
Power factor	0.8leading ...0.8lagging	0.8leading ...0.8lagging	0.8leading ...0.8lagging	0.8leading ...0.8lagging
THDi	<3%	<3%	<3%	<3%
AC grid connection type	3W+N+PE	3W+N+PE	3W+N+PE	3W+N+PE
Efficiency				
Max.efficiency	98.8%	98.8%	99%	98.8%
Euro - eta	98.3%	98.3%	98.4%	98.3%
MPPT efficiency	99.9%	99.9%	99.9%	99.9%
Protection Devices				
DC reverse polarity protection	yes	yes	yes	yes
DC Switch	yes	yes	yes	yes
DC Surge protection	Type II	Type II	Type II	Type II
Ground fault monitoring	yes	yes	yes	yes
Output short circuit protection	yes	yes	yes	yes
AC Surge protection	Type II	Type II	Type II	Type II
String fault monitoring	yes	yes	yes	yes
Anti-PID protection	opt	opt	opt	opt
General Data				
Dimensions (W / H / D) in mm	860/600/300	860/600/300	860/600/300	860/600/300
Weight	82kg	82kg	82kg	82kg
Operating temperature range	-25°C ... +60°C	-25°C ... +60°C	-25°C ... +60°C	-25°C ... +60°C
Noise emission (typical)	≤55dB(A)	≤55dB(A)	≤55dB(A)	≤55dB(A)
Self-Consumption	< 1W*	< 1W*	< 1W*	< 1W*
Topology	Transformerless	Transformerless	Transformerless	Transformerless
Cooling concept	Smart cooling	Smart cooling	Smart cooling	Smart cooling
Environmental Protection Rating	IP65	IP65	IP65	IP65
Altitude	4000m	4000m	4000m	4000m
Relative Humidity	0-100%	0-100%	0-100%	0-100%
Features				
Display	LED/WIFI+APP	LED/WIFI+APP	LED/WIFI+APP	LED/WIFI+APP
Interfaces:USB/R485/GPRS	yes / yes / opt	yes / yes / opt	yes / yes / opt	yes / yes / opt
Warranty:5 years / 10 years	yes / opt	yes / opt	yes / opt	yes / opt
CQC, CE, VDE 0126-1-1, UTE C 15-712, VDE-AR-N4105, EN50438, DRRG, CEI 0-16, BDEW, IEC 62116, IEC61727, IEC 60068, IEC 61683, AS 4777				

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