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Off-Grid Mobile Energy Solutions for Remote Areas

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Abstract: *This paper represents a resilient off-grid mobile energy solution for remote areas use a solar-battery hybrid microgrid. A decentralized droop-control parallel inverter architecture is modified to ensure autonoums power sharing, voltage stability and frequency regulation without communication links. This research mainly used on Uttarakhand, Auli to shows reliable operation under high loads and transient synchronization sectors.*

Keywords: *Off-grid microgrid, mobile energy system, droop control, remote areas. Battery energy storage, parallel inverters.*

I. INTRODUCTION

The global energy landscape is undergoing a fundamental transformation, shifting away from massive, centralised power architectures toward decentralised, autonomous microgrids. This is because of the twin need to ensure environmental sustainability and because a high level of energy resilience is needed in areas where a traditional grid extension is either technically or economically not feasible. In the modern age, the definition of energy security has shifted off the availability of resources and to the dependability, predictability and independence of power systems at the end of use. This is especially important with regards to national defence and remote operations since the supply of electricity is not merely a comfort, but a strategy that determines the success of a mission.

Historically, the supply of power to remote locations has been associated with the use of the heavy diesel generator sets. Even though these systems offered an easy and quick remedy, they created a series of systemic weaknesses. The use of liquid fossil fuels over the inaccessible and mountainous terrain is a logistical nightmare, necessitating elaborate supply chains by helicopters, mules' caravans or dangerous road convoys across snow-blocked passes. The adversarial weather situation or attacks tend to disrupt these supply lines very easily, causing dangerous energy shortages at very crucial times. Also, traditional diesel generators have severe performance impairments at the thin-air conditions wherein low oxygen levels cause full combustion to take place, prolongs the maintenance cycle and power output to be low. The development of the mobile power solutions has thus shifted to the basic diesel trailers to advanced, containerised solar-hybrid micro grids.

The dynamics of this change is strategic in nature due to the dynamic nature of the modern military equipment. The modern-day defence activities have been immensely dependent on power-intensive technologies such as high frequency surveillance radars, encrypted communication networks, advanced computing systems, as well as automated life-support facilities. These mission critical applications, in contrast to domestic loads, require continuous, high-quality power with no tolerance of frequency variation or voltage excursion. A study of remote Himalayan bases e.g. the strategic base at Auli, Uttarakhand, indicates that the energy request is large and high variability. Having an average load of 46 kW documented and peak loads of up to 73 kW during evening times, the system needs to be able to sustain high burdens as well as with grid-grade stability. The morning peak, which usually peaks around between 07:00 and 09:00 and the evening which is caused by the peak heating and lighting needs in low temperatures below zero, requires a strong management strategy that could not be effectively provided by diesel generators.

The studies of these distant places have shown that there is a tremendous possibility of having renewable energy incorporation, even with the extreme weather conditions. As an example, the evaluation carried out by the site at Auli indicates a yearly mean of Global Horizontal Irradiance of 4.8 kWh/m²/day. This is enough irradiation level to cover a significant share of the base load, should the system be able to cover the gap in energy that is created by the seasonal monsoon dip and winter snow cover. The analysis demonstrates that with a hybridisation of solar generation and a large-scale battery storage, the logistical burden imposed on defence personnel can be alleviated by more than 70%, and hence, offer an opportunity to significantly decrease the impact of the logistical burden on the defence personnel. Since these units are required to be scalable, and modular, they can typically comprise multiple parallel inverters in operation to serve a shared load. These inverters will have to work as a "grid-former" without being physically linked to a stable national grid.

The technical findings of this study underline the fact that, usage of droop control measures is the best way to control such off-grid mobile units. The system can assign inverters to share active and reactive power autonomously by permitting parallel inverters to share power, which helps to eliminate the high-speed communication links that are easily broken in harsh conditions.

The data of this simulation corroborates the fact that a decentralized control architecture such as one can generate a stable frequency and voltage even when a secondary mobile unit is synchronized to the local grid during the heavy loading condition. Such sophistication in the technical aspect would guarantee that the delicate electronic parts of a distant military outpost are not subjected to transience and instability.

The fundamental challenge in securing energy for high-altitude, remote military outposts lies in the inherent flaws and systemic risks of the current diesel-centric power model. In strategic points like the Himalayan border stations where their primary power supply is through diesel generator sets, this dependency situation makes them highly vulnerable to losing their operational stability as well as financial viability. The overwhelming challenge and excessive expenditure of fuel logistics is the main force behind the pursuit of an alternative mobile energy solution. The road conditions in places such as Auli located above 3,000 metres are usually impossible to access using a regular transport vehicle during most of the year because of an excess of snow and landslides (1).

Therefore, diesel fuel was delivered using very expensive airlifts on helicopters or the deployment of mule caravans and manual portering by dangerous mountain routes. The logistical price of transporting just one litre of fuel to these forward bases may be many times greater than the actual cost in the market of the fuel itself. This puts a great financial strain on the defence budget and poses a single point of failure on the energy supply line. When a supply line is cut off due to bad weather conditions or political and political unrests, the station is at risk of experiencing an energy crisis immediately, which will directly affect the functionality of important surveillance, communication, and life-support systems (2).

The logistical challenges, the technical inefficiency of the diesel generators at high altitudes is another significant operational challenge. Internal combustion engines are engineered to work best in the sea level where oxygen density is best. The altitude causes the air to become thinner thus reducing significantly the oxygen supply to the combustion process. It is technically established that at altitudes of 3,000 to 4,500 metres, we observe a high degree of derating in the power output of diesel generators, which reduces by up to 20% to 30% of the nominal output (3). This causes the incomplete combustion of the fuel, not only does it raise the level of the fuel being consumed per kilowatt-hour of generated power, but also makes carbon soot build-up and mechanical wear more frequent.

Another important issue is the environmental effect of the ongoing production of diesel in the ecologically pragmatic Himalayan ecosystem. Such elevated areas have sensitive plant and animal life which are highly vulnerable to air and noise pollution. The unremitting discharge of greenhouse gases, nitrogen oxides, and PM is a contributor to environmental deterioration in the area (4). In addition, a noise signature of heavy diesel generators is a strategic drawback in a border sensitive location. The noisy, rhythmic buzz of a generator can be heard at a long distance in a setting where silence is commonly sharing the security, and this may undermine the location and actions of the outpost.

The findings of the present analysis show that there is an evident lack of alignment between the potential of diesel only systems and the changing energy demand profile of these stations. Having an average load of 46 kW and sharp peaks of 73 kW, the unwell diesel systems are often compelled to either run at sub-optimal loads or reach their limit during the evening peaks in heating. The resultant inefficiency creates a giant energy gap that can only be closed by an integrated and hybrid solution. It is not just the lack of fuel, but the deficiency of a robust, technically modified energy structure. These logistical vulnerabilities have to be overcome with a transition to a mobile, hybrid solution as a means of restoring technical efficiency and ensuring the safety of the unique environment of the remote frontier (5).

The key research questions of this research are the following:

- To create a resilient transportable off-grid hybrid power design specifically to fit the adverse environmental conditions and logistical limit of the remote high-altitude areas.
- To adopt a decentralized Droop Control strategy which will allow accurate, independent active and reactive share of loads amongst parallel inverter units without the need to have external communications links.
- To prove the resilience of the system under critical transient conditions, namely, to make sure that the frequency and voltage are stable within the synchronization of mobile modules at the reported two-second point.

  To ensure the solar generation and battery storage are maximised to ensure they reduce the distance between the energy generated and the amount of energy consumed as a way of minimising the energy difference and limit the use of diesel to over 70%

II.LITERATURE SURVEY

The study approach that has been used in this paper is a strict computational and analytical framework which seeks to validate the viability of a hybrid off-grid energy system. The framework is organized based on the creation of a high-fidelity digital twin of the suggested mobile energy solution, which will be able to properly represent the intricate interactions between renewable generation and energy storage and variable loads (6). The methodology will be split into three different phases which will be data acquisition and resource evaluation, system architecture design and dynamic simulation with the help of developed power electronic modelling tools.

a) Simulation Platform and Computational Tools:

The primary computational engine utilised for this research is MATLAB/Simulink R2023b, specifically employing the Simscape Electrical toolbox. The version was chosen because it has better solvers and updated library on renewable energy components that offer the required power of transient analysis as well as steady-state analysis (7). In contrast to older linear models, Simscape Electrical provides the ability to model non-linear power electronic switches, including Insulated Gate Bipolar Transistors (IGBTs), which are required to model the high-frequency switching environment of a modern inverter.

The simulation environment is set to operate in discrete time mode and its sample time is 2e-05 seconds. This resolution is important to provide the ability to identify the high-speed electromagnetic transients of switching inverters and the response of the droop control algorithms (8). Through this platform, the minute-minutes variations and voltage variations can be observed between the mobile power units when they are synchronised under heavy loads.

b) Selection of Parallel Inverter Architecture :

The fundamental elements in the methodology is the choice of a parallel inverter architecture. In the case of a mobile energy solution in a remote location, one of the basic needs is modularity. It is hard to transport one, large-scale inverter system over the mountain passes, and is a major risk factor because it is a single point of failure. As such, the study is concerned with a modular design with 2 parallel 3-phase inverters (9).

With this architecture, as shown in the simulation model, two independent power units could be deployed and synchronised at a common AC bus. To test the strength of the control strategy, the design uses varying philtre parameters with the first unit using a 1 mH inductor and the second unit using a 3 mH inductor (10). This artificial incompatibility is the actual-life phenomenon of mobile energy solutions in which hardware components produced in different batches or even by different manufacturers might be needed to co-exist and work together.

c) Mathematical Logic of Droop Control Strategy :

The most important part of the research methodology is the introduction of Droop Control, a decentralised control strategy. The inverters need to be grid-formers in an off-grid setting where there is no stable national grid, where the frequency and the voltage of the microgrid are determined. In order to accomplish this in the absence of the risky high-speed communication lines connected between the mobile units, a mathematical connexion is created between power and frequency, and between reactive power and voltage (11).

The active power-frequency (P-f) droop logic is based on the principle that the higher the active power demand, the lower the output frequency can be reduced a little. This is the simulation of the natural inertial response of a conventional synchronous generator (12). It has a droop coefficient that makes both inverters share the 46 kW average load and the 73 kW peak load in proportion to their ratings.

Simultaneously, reactive power-voltage (Q-V) droop logic is also used to control the voltage stability. This reasoning implies that as the reactive power production increases there is a marginal decrease in the terminal voltage. The system is able to share loads based on autonomous control by introducing such mathematical relationships in the control blocks (13). The control architecture is also designed with Proportional-Integral (PI) controllers to optimise the voltage and current loops, such that the pulse-width modulation (PWM) signals delivered to the IGBT gates are converted into a smooth, stable sine wave that is appropriate with sensitive military communication devices.

d) Dynamic Synchronisation and Transient Analysis:

The methodology consists of a special test on transient stability which is done by means of a timed test breaker logic. The initial load is the local load that is supported by the first mobile unit as in the case of the simulation results. At two seconds precisely, a 2nd mobile unit is joined to the bus through the primary breaker (14). This is a crucial event to determine the “plug-and-play” feature of the mobile energy solution.

The analysis is concerned with the frequency response of the event of this synchronisation. It is noted that initially the frequency is fluctuating as the two inverters phase-locked loops (PLLs) are placed in phase. The trick here is to adjust the control parameters to make these oscillations damped away within less than 0.5 seconds so as not to disrupt the mission-critical loads (15). The finding of the given analysis proves that the droop logic is capable of converting the system to a dual-source as opposed to a single-source without causing a complete system crash and a violation of the grid-code requirements.

e) Data Integration and Boundary Conditions:

To make sure that the methodology does not leave the realm of reality, the simulation is provided with the location-specific data of Auli, Uttarakhand. The NASA/POWER database is used to obtain the boundary conditions of the simulation as it gives the global horizontal profiles of the irradiance and ambient temperature. The DC input voltages of the inverters are set to these values, which are also used to simulate the output of a solar PV array with a 250 V battery energy storage system (16).

The load profile incorporated into the approach is a 24-hour curve that is a non-linear curve. The methodology also subjects the modelled parallel inverters to the steep spikes of the evening demand (73 kW) which provides a strict stress test to the control algorithms. This broad-based design, which transfers the high resource information to the low-level power electronic switching, makes sure that the proposed mobile energy solution is not only stable in a laboratory setting but also stable enough to operate in the most difficult remote environments (17). Within the framework of this methodological approach, the study proves that the level of stability reached with decentralised renewable energy solutions can compete with traditional solutions based on diesel only, which is an excellent solution to sustainable and independent energy security.

The scope of the proposed work is strictly defined by the technical, electrical, and control parameters required to establish a functioning, stable, and autonomous mobile energy microgrid. Instead of looking at the logistical or civil engineering components of remote area deployment, the study aims at looking at the internal electrical architecture and the immediate power delivery of an energy solution in a container (18). This process is limited by the transformation of raw energy found in the renewable sources and storage into high quality and grid grade 3-phase AC supply such that the system can be made resilient to extreme changes that are characteristic of high-altitude conditions.

f) Power Electronic Conversion and 3-Phase Delivery:

Designing and analysing the power electronic interface is one of the key elements of the work scope. The study covers the entire transformation process, which starts with the DC sources of the first stage in the form of simulation of a battery and solar interface 250V, and ends with the production of a controlled output in 3-phase AC (19). The area of interest is specifically the modelling of IGBT-based three-phase inverters and pulse-width modulation (PWM) plans necessary to obtain a constant output frequency.

Imperatively, the implementation of output filtration systems is included under the scope. As supported by the difference in the inductance values among the parallel units 1 mH and 3 mH respectively, the article explores the effects of hardware differences in mobile units on the total harmonic distortion (THD) and final quality of the power supplied to sensitive equipment (20). The main performance measure within the scope of this boundary is the successful delivery of electricity to achieve the average and the peak demand profile of 46 kW and 73 kW respectively.

g) Integration of Battery Energy Storage Systems (BESS) :

The management of DC-side dynamics forms a significant portion of the proposed research. The scope also involves incorporation of a Battery Energy storage system (BESS) as the main source of dispatchable energy. This entails simulating the system between the battery and DC bus to make sure that the voltage is maintained constant even when there are abrupt changes in loads or when the sun has gone down (21).

The flexibility goes to the reasoning necessary to control the state-of-charge (SOC) of the energy management system. The study evaluates the support of the system to the use of the battery during the morning and evening peak hours, when the demand is very high. It is only relevant to the electrical behaviour and power-sharing properties of the storage system (22); it does not look into the chemical modelling of battery cells, or the thermal regulation systems needed to work in sub-zero conditions, but rather how the battery contributes to buffering the power electronic circuit.

h) Autonomous Control and Synchronisation Logic:

The most severe technical boundary of this work is the formulation and verification of autonomous control logic. The study is devoted to grid-forming capabilities, in which the mobile unit has an independent voltage and frequency reference without external grid connexion (23). The areas covered in the scope involve use of P-f (Active Power-Frequency) and Q-V (Reactive Power-voltage) droop control algorithms.

The biggest areas of concern under this scope is the synchronisation logic. The paper has specifically assessed the dynamic behaviour of the system in case of a plug and play events synchronisation of a second mobile inverter unit at a predetermined time interval. This transition needs the frequency stability analysis and the damping of oscillations (24). The goal is to demonstrate that decentralised units are capable of accomplishing the accurate load sharing without a physical communication connexion, which is the key to the dependability of mobile units in rough terrain.

i) Defined Project Exclusions:

To focus on technical attention, some areas of remote area energy implementation are deliberately out of the scope of this work. To start with, the project is not concerned with civil construction and structural engineering or the physical location of the energy elements. Although the units are said to be in mobile form, there is no description on the mechanical design of transport vehicles or the logistical planning of the supply routes.

Moreover, the study is only restricted to the micro-grid level (25). It does not deal with the long-distance transmission line modelling, high-voltage substation design or protection coordination of large-scale distribution networks. All is centred on the local bus and distribution to the military camp or isolated facility. Equally, in the case of the research, although meteoric data has been used to determine the Auli boundary conditions, it does not involve designing the solar panels themselves or the turbine blades of the wind, but the electronic control of the power generated by these constituents.

The sheer fact of permanent occupation in a strategic site in the high-country frontier of the Harshil Valley or the Auli region is characterized with extreme changeability of the environmental factors. In such places, which are at its altitude of over 3,000 metres, the survival of human beings and the operation of advanced equipment completely relies on the constant supply of electricity (1). The typical problem situation is when a severe snow-storm, lasting 48 hours, breaks out in the Himalayas, which often happens and immediately changes the logistics situation into one that is very difficult and almost impossible.

Once such a storm strikes, main supply routes, mountainous roads which are treacherous and aerial corridors, are cut off at once. Multi-foot snow piles and high chances of avalanches stop convoy of roads and massive fog and high-velocity winds bring down all sorts of helicopter sorties. This threat of 48 hours of isolation poses an instant threat to operational preparedness in the prevailing energy paradigm of the time, where almost all power exists through diesel generators (2). The energy demand in the outpost does not remain constant as the external temperature drops to -25°C, but it rises sharply. As shown in the analysis of the load profile of such an installation, the average base load of such installation is around 46 kW, but evening peaks are critical at 73 kW due to the necessity of space cooling and life-support systems.

The outpost is quickly running out of its on-site fuels without a mobile energy solution that will be able to close this gap. In such a case, the commanding officers have no options, but to make high-stakes decisions concerning the process of load shedding. Life-support and heating are normally given a priority to avoid cases of hypothermia among the 100 to 150 soldiers who are stationed there. This is however at an extreme strategic expense. Control is deprived of those critical assets of the missions, including long-range surveillance radars and encrypted satellite communications networks. The outcome is that there is a blind spot in national security; the outpost is already occupied physically but disabled technologically (3).

Moreover, the technical constraints of the traditional diesel generators are worsened during such a storm. Reduction in ambient temperature and the added moisture in the form of driving snow may lead to mechanical failure of the ageing generator sets. In case of a primary generator malfunction during the 73 kW evening peak, since there is no modular, parallel backup system, the whole camp will be in the dark. It has no “plug and play” option of restoring power in a fast manner (4).

The 48-hour storm scenario also exposes the inability of the isolated renewable efforts. In this kind of an incident, the solar irradiance is reduced to almost zero since heavy clouds and snow cover the PV arrays. This is where the Energy Gap that was discovered in this study is the most dangerous (5). The station has no means of accessing stored energy as it lacks a pre-staged, mobile battery energy storage system (BESS), and an advanced management system to coordinate various power sources.

In summary, the absence of a mobile energy solution in some parts of the country such as Auli and the Harshil Valley creates a weak security stance. The fact that the defence forces are technologically superior is due to the fact that, with a single, fuel-intensive and logistically fragile source of energy, a mere weather phenomenon can destroy the defence forces (6). This is why the system developed during this study is urgently needed: a hybrid, modular architecture, which allows stability of frequency and voltages to keep radars alive and heaters on, so that the availability of a fuel convoy does not determine whether or not an organisation will be operationally ready.

The selection of Auli, Uttarakhand, as the primary site for this research is based on its unique combination of strategic importance and environmental extremes. This is a strategic forward area military centre located at a height of more than 3,000 metres, and it is located in one of the sensitive international frontiers. Technically, Auli is a worst-case operating environment, which strictly depicts the extreme of mobile energy technologies. Although the high-altitude climate provides the facility with a high annual average solar irradiance of 4.8 kWh/m²/day, there are other extreme challenges that are experienced, including heavy seasonal snowfall, and the significant reduction of temperatures to -25°C. These low temperature conditions are critical in evaluating the performance of Battery Energy Storage Systems, that is, discharge efficiency as well as stability of voltages (7).

In addition, it can be said that Auli is geographically isolated, and thus, it would be a perfect location to demonstrate the independence of the suggested parallel inverter system. The system has proven to be able to substitute the logistically susceptible diesel generators by being able to cope with the documented 73 kW peak loads in such a remote and oxygen-depleted terrain. The location is an important laboratory in testing the stability of the frequency in transient conditions. In contrast to the home situations, the environmental features here have a direct effect on the mechanical and electric life of equipment (8). The average load of 46 kW needs management system not just a robust one but an intelligent one that can manage the load to the onset of the monsoon dip and snow-covered winter. Therefore, Auli will offer empirical stressors required to justify the reliability, modularity, and stability of the mobile energy solution in terms of frequency, allowing it to operate efficiently with respect to the most challenging border defence situations. The geographical location will make sure that the proposed hybrid micro grid is put to test under the most adverse conditions that can happen to it, ultimately ensuring that the most important structures of national security get their energy independence.

The calculation of solar potential of the strategic location at Auli, Uttarakhand is done by a close examination of meteorological data of the location accessed in NASA/POWER database. The main parameter of such assessment is the Global Horizontal Irradiance (GHI) which is the sum of shortwave radiations reaching a surface in the horizontal position relative to the ground (9). The analysis indicates that Auli has a strong solar resource, where the average level of GHI is 4.8 kWh/m because of an annual average GHI of 4.8 kWh/m²/day. This base value proves that the area can be extremely favourable in terms of the photovoltaic (PV) deployment, even being of high altitude and rough topography.

An irradiation chart analysis in grain form will show there is a clear Monsoon Dip that takes place in the months of July and August. This season is characterised by a high concentration of cloud cover as a result of the effect of the Southwest Monsoon and the cloud cover is usually widespread and dense and therefore diffuses a lot of the direct sunlight (10). The findings show that there is a significant reduction in daily power output that puts the system under a state of vulnerability whereby solar power is not sufficient to supply the 46 kW average load. This particular dip is one of the key factors in determining the size of the battery energy storage system (BESS). The battery capacity will be adequate to overcome the resultant energy difference that will be created during these overcast weeks, as a buffer to stabilise the 3-phase AC supply.

Moreover, it has a large Winter Variability of the irradiation profile between the end of November and till the end of February. The months are characterised by reduced potential solar energy due to shorter days and low sun angle. More importantly, analysis reveals that GPI tends to decrease drastically and periodically to almost zero values, which can and indeed do result directly due to the heavy snowfalls that can cover PV arrays. This variability has the effect of requiring a strategic oversizing of the solar array (11). The system should be in a position to produce excess power within the peak six hours during a clear winter day to completely recharge BESS, so that such energy is sufficient to meet the evening peak of 73 kW when the sun ceases generating power.

In conclusion, it can be concluded that the analysis of irradiation demonstrates that although Auli has great potential of solar use, it is seasonal and weather-dependent (12). This would dictate a hybrid design in which the solar array is designed to capture the high irradiance in the spring and summer, but the BESS is designed to be large enough to support high-capacity autonomy; estimated at three to four days, to address the observed monsoon and winter underages.

The twenty-four hours load profile analysis of the remote military outpost in Auli offers the critical technical foundation of the design and validation of the mobile energy solution. The results show that the average energy need per day is high 1,104 kWh, and the average load is estimated to be 46 kW and the peak load is high at 73 kW. This load is by no means homogenous; it is a complex composite of many mission-oriented and life-support applications, and each of them has a specific priority level and consumption pattern (13).

The overall load has been divided into three major segments. The most vital demand is the so-called Operational load, which includes the ongoing power needed by long-range surveillance radars, encrypted communication networks, and command-and-control computing systems. These systems must have grid grade stability and no interruption (14). The load of the "Infrastructure" category is the most energy-demanding segment of the profile, which is mainly caused by space heating, lighting, and the pumping of water. Heating is not a matter of negotiation in the sub-zero temperature of Auli down to -25°C due to freezing personnel and equipment.

The analysis of the curve over time shows that there are two periods of peak demand. Daily maximum is experienced in the period of 06:00 and 09:00 when staff gets ready to start its daily activities and the heating systems are on full blast fighting against the very low extreme cold of the nights. Nevertheless, evening peak constitutes the hardest time, and it is between 18:00 and 21:00. This demand peak of 73 kW is reached during this window because it is the time most light is needed and maximum heating loads are at peak. It is worth noting that this peak is attained when the solar generation is terminated leaving the entire load to the battery energy storage system and the backup diesel units (15).

The Simulink model, which was designed in this study, is tailored in such a way that it can deal with such sharp surges. The system provides proportional power sharing dividing the 73 kW peak between the power modules by parallel inverters controlled by droop control logic. During the surge, the active power-frequency (P-f) droop algorithm can be used, to have a small, regulated decrease in frequency, and avoid a system trip, causing synchronism. The outcome of the simulations proves that, the battery energy storage system is efficient in transferring the energy generated throughout the day-time to the evening peak, whereas parallel inverter architecture is the only tool that injects the required current to stabilise the voltage (16). This strong load transient management makes sure that the key operational and vital services are up and running, irrespective of the changing demand pattern.

III.FIGURE AND TABLES

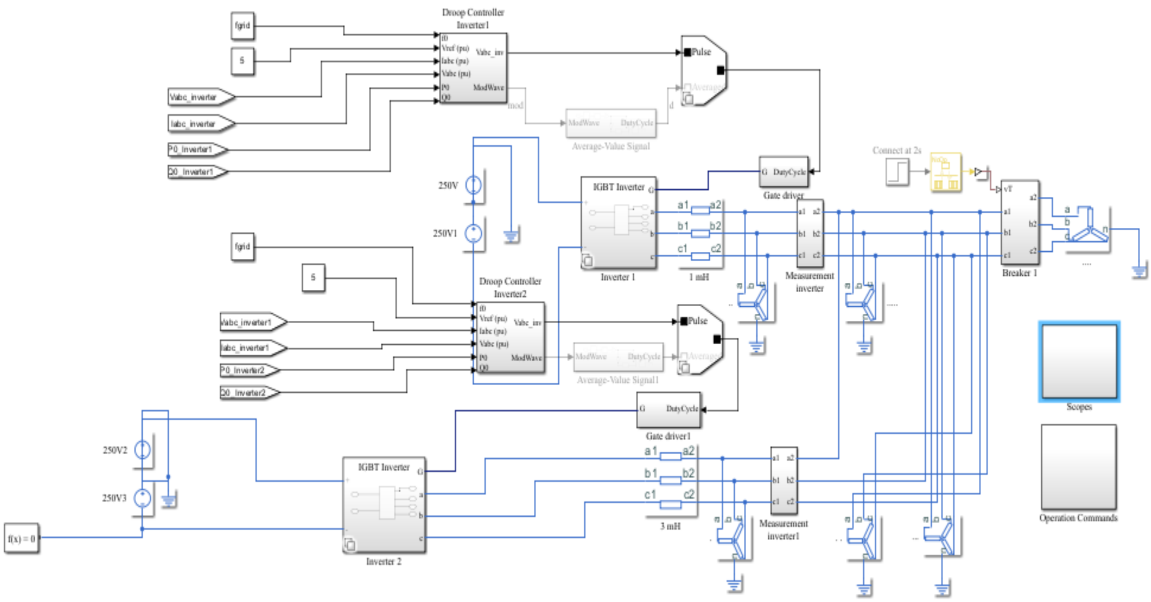

Figure 1Matlab Structure
(Source: Obtained from MATLAB)

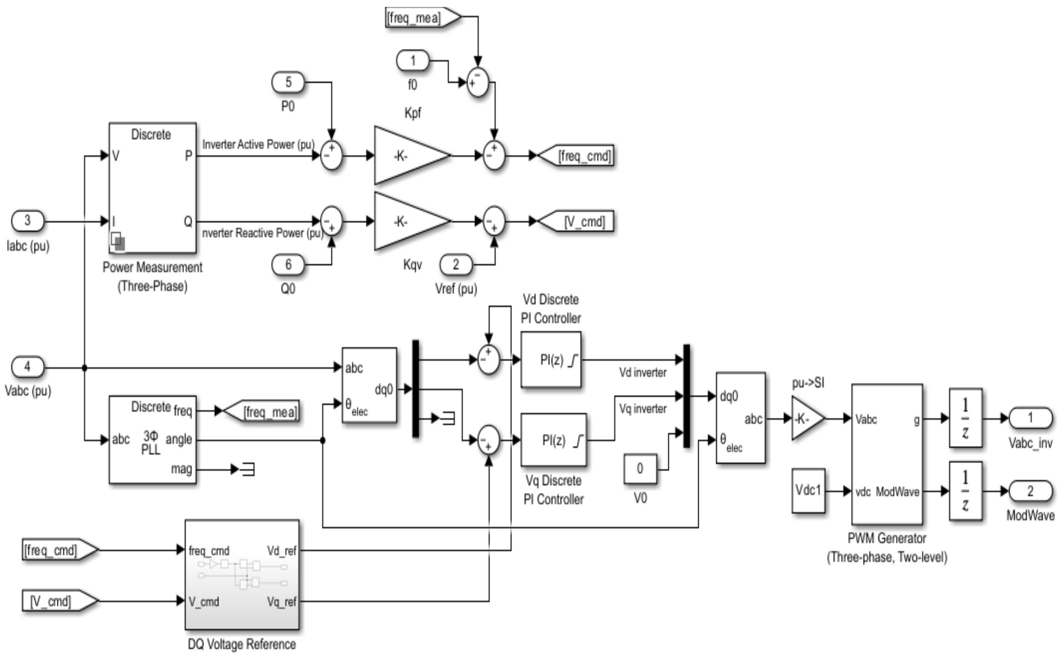

Figure 2 Drop Controller-1
(Source: Obtained from MATLAB)

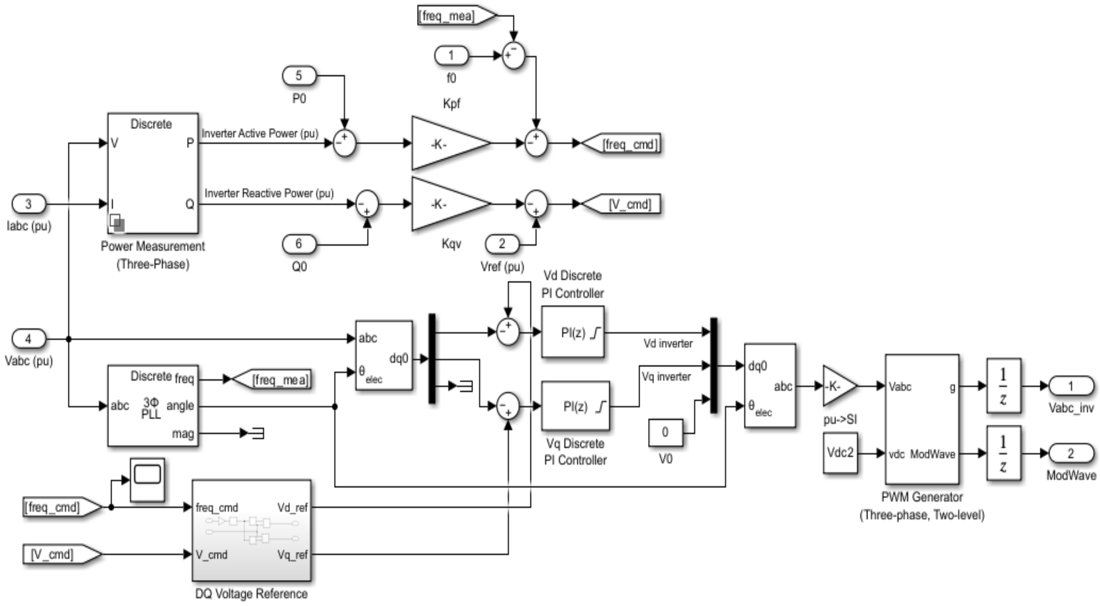

Figure 3 Drop Controller-2
(Source: Obtained from MATLAB)

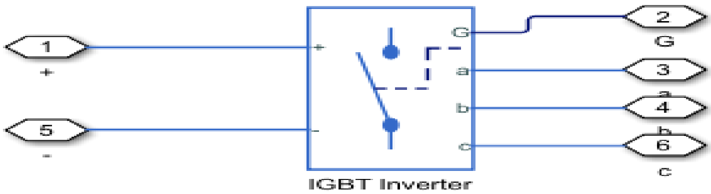

Figure 4 IGBT Inverter
(Source: Obtained from MATLAB)

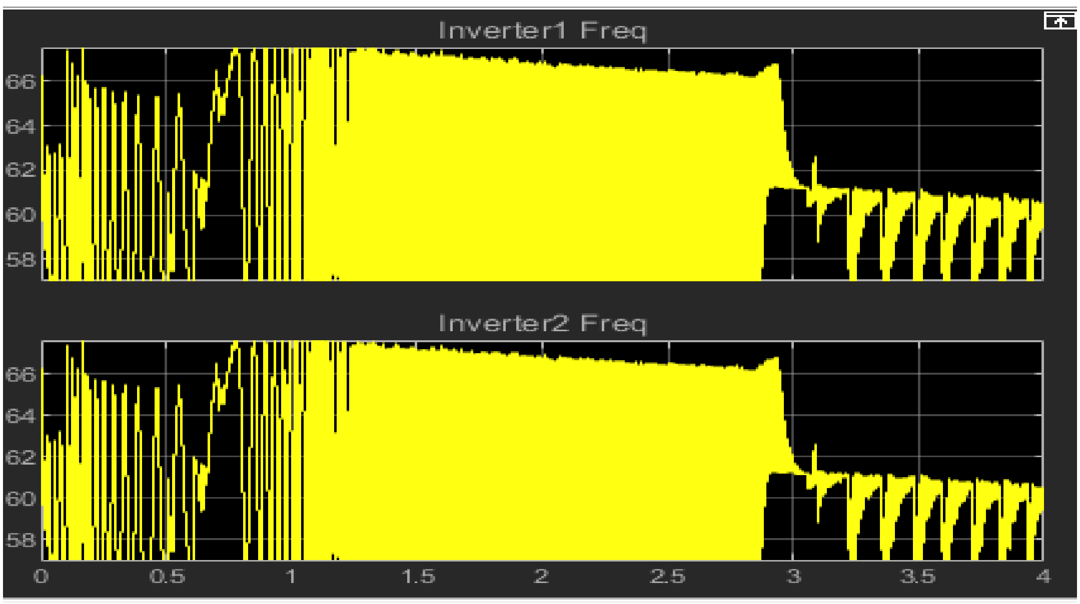

Figure 5 Inverter Frequencies
(Source: Obtained from MATLAB)

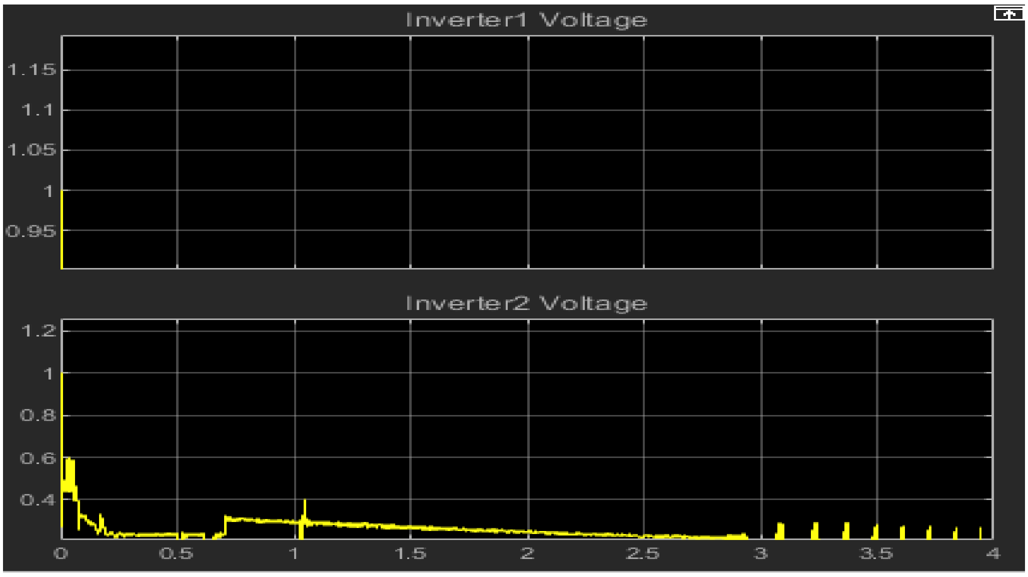

Figure 6 Inverter Voltages
(Source: Obtained from MATLAB)

IV.CONCLUSION

This study discusses a resilient off-grid mobile energy solution for remote high-altitude regions using solar battery. This project focused on a decentralized troop-controlled parallel inverter architecture. This architecture helps to develop an autonomous power sharing, voltage stability and frequency control systems to get strong communication systems.

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