University of Rwanda

College of Science and Technology

DESIGN AND ANALYSIS OF AN INVERTER FOR GRID CONNECTED MICRO PV POWER PLANT

THESIS

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DECLARATION

I, the undersigned, declare that this thesis is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials that will be used for the thesis work will have been fully acknowledged.

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CERTIFICATION

This thesis has been submitted for examination with my approval as a university advisor.

Thesis Advisor: **Dr. Peter Musau** Date of Submission: 20/11/21

Signature:

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ABSTRACT

To enhance the performance of photovoltaic technology in addition to the power quality, The inverter grid-related for PV technology was carried out. This thesis is composed withinside the layout of an inverter linked to the grid to deliver electricity to a small a part of the populace of Goma, a town positioned withinside the east of the DRC withinside the province of North Kivu. there may be an actual want to apply renewable electricity assets which include sun electricity to conquer the common load dropping withinside the town. This want has been accentuated withinside the town of Goma given the expanded density of the populace and no matter the actual efforts made withinside the personal area to enhance the delivery of electrical electricity, a massive a part of the populace isn't always electrified, and the contemporary power distribution networks stay alternatively vulnerable or unreliable.

Based on a few present-day research at the incremental conductance method, a superior incremental conductance manipulate algorithm was proposed, that can track maximum power point swiftly and accurately. The oscillation phenomenon, which exists close to the maximum power point, was progressed at a high-quality extent, to the efficiency of photovoltaic cells technology electricity. The inverter control device has an advantage in its immoderate speed and flexibility with the resource of the usage of applying advanced control algorithm. And the deliver harmonic current is remarkably reduced. An effective solution is the usage of solar inverters feeding the grid with alternating current may be a real advantage. In this thesis we have got designed and analyzed an inverter, which can be applied to grid connected photovoltaic production. To validate the outcomes of this work, MATLAB / Simulink software program software modified into used for the simulation. The final result got using 500 photovoltaic cells in serial and 1000 in parallel, under the environment temperature of 300K, standard temperature 1000W / m2 , the grid voltage of the selected site 220V , 50Hz , intermediate DC bus voltage 450V , with the simulation time of 0.4s , confirmed that the advanced control system of the grid current inverter, which has an inclination withinside the direction of the sine wave, waits until it reaches the maximum energy factor tracking, similarly, to being able to place an power arbitrary to load or network, at the same time as the control system has correct stability.

Keywords: Grid Connected, Micro-PV, (PED) Inverter, PV System.

LIST OF SYMBOLS AND ACRONYMS

ANN: Artificial Neural Network.

DF: Demand Factor.

DRC: Democratic Republic of Congo.

IEC : International Electric Commission ;

INS : Institut National de Statistique ;

LF: Load Factor.

PED: power electronic device

PQ: Power Quality

PV: Photovoltaic.

RE: Renewable Energy.

SD: Sustainable Development.

SNEL : Société Nationale d'Electricité ;

SOCODEE : Société Congolaise d'Eau et d'Electricité ;

Kv: Kilo Volt

kVA: Kilo Volt Ampere

kVAr: Kilo Volt Ampere Reactive

kVArh: kilovolt-ampere hour

kWh: Kilo Watt-hour

L: Load

LDF: Load Factor

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CHAPTER 1

INTRODUCTION

1.1. Background

Goma town is provided with the aid of using the National Electricity Company SNEL, which comes from the RUZIZI1 energy plant located in South Kivu province which can provide round 12MW. For a while now different personal corporations inclusive of Virunga Sarl Energy which in flip offers 10MW, with a production of 13.2MW, NURU Energy company has been connecting an off-grid solar energy plant since February 2020 which distributes energy from approximately 0.268MW withinside the town, with an output of 1.2MW. The general energy added may be expected at the least 23.2 MW, for a want predicted at 80MW in 2020 through the PNUD. There is consequently an actual imbalance among production and the want in terms of electrical power. Access to electric power consequently stays an extreme problem for a big a part of the populace of Goma however additionally and above considering the agricultural populace of North Kivu. This manifests itself withinside the non-electrification of villages, neighborhoods, and municipalities.

Consequently, to satisfy the actual demand for electricity, the populace of the Goma city has recourse to different assets of energy, especially charcoal, kerosene because, despite the efforts made so far, there, in the personal sector, the delivery of electrical power stays insufficient, and get entry to be pretty limited.
Nowadays, the production of photovoltaic energy on a large scale is a key concept and essential in the development strategy, but the challenge remains to discover a manner to sell the improvement of the photovoltaic industry. Similarly, because of its personal traits special from fossil production, the grid-connected photovoltaic power plant its safety, balance and reliable operation are real challenges for the grid.

However, strategies of inverter manipulate are required, the voltage supply inverter manipulate approach and the electricity kind PWM inverter manipulate approach which might be usually used nowadays. The voltage supply inverter manipulate approach regulates the segment attitude to the grid particularly thru receiving voltage alerts from the *DC* facet of the inverter, known as outer loop, to manipulate the grid voltage, even as it regulates the reference of the weight voltage at the *AC* facet to manipulate the output of the modern-day inverter, that is known as the inner loop. However, the internal loop method does now no longer influence the consequences of the outer loop in any way. The required electricity may be acquired through converting the modulation charge of the PWM inverter.

For masses that use AC to paintings well an inverter is needed to extrade the supply polarity and to synchronize the generated electricity with the electrical grid electricity in a few cases, given that photovoltaic modules produce electricity in DC. In any set up of a related grid, the exigencies at which inverters should meet are yield exigencies and prison exigencies. Yield exigencies incorporate the capability, the density of the electricity, fee of set up, and minimization of leakage current. The type of prison exigencies entails isolation via galvanic, detection of anti-islanding, and different technical codes [1]. Solar Inverter may be carried out in numerous topologies that can contain the manner to interconnect the Photovoltaic modules among them and the inverter in addition to their likely applications. Therefore, based on that we have: Central inverters, String inverters, Multi string inverters, Module integrated inverters, Mini central inverters.

1.2. Problem Statement and Justification

The metropolis of Goma is positioned withinside the jap a part of the DRC withinside the province of North Kivu is in the southern hemisphere, with latitude 1 67409 and longitude 29 2284 being its geographical coordinates. The city is currently furnished. via way of means of 3 huge strength flowers namely, Ruzizi withinside the province of Bukavu in South Kivu with a mean ability of 12 MW transmitted; Matebe in Rutshuru with a mean ability of 10 MW transmitted to the metropolis and the NURU sun strength plant withinside the metropolis of Goma with a complete ability of 1.2 MW. The 3 strength flowers also are now no longer interconnected and feature terrible reliability while presently round eighty MW of electrical strength is wanted withinside the metropolis of Goma, however best round 23.2 MW of strength is furnished in general account. The deficit of electricity that's round 56.8 MW is simply the primary motive of many loads losing withinside the metropolis. According to the ARE (power regulatory authority) withinside the DRC, the charge of get right of entry to electricity withinside the metropolis of Goma is 4% and primarily based totally at the goal target to attain to 30% charge in 2024 in DRC. The present day get right of entry to electricity stays a severe difficulty for the metropolis of Goma. Thus, Goma's populace makes use of different assets of energies, inclusive of biomass (charcoal used), kerosene and small diesel generator. These highlighted energies assets utilized in Goma con-tribute negatively to weather change. To meet the actual call for power, he'll discover options which can be more secure and less complicated to installation, hydropower is unluckily restrained however additionally and, it’s putting in is extraordinarily expensive. So, the use of solar electricity is a far higher choice due to the fact it's far al-equipped loose at the bottom however additionally easy to installation and capable of offer a strength huge sufficient to absolutely catch up on this actual deficit in electric electricity withinside the building. City of Goma particularly and withinside the DRC (Democratic Republic of Congo) in general. Therefore, the main purpose of this thesis is to design and assess a layout PED (Dower Electronic Device) an inverter that may be the gadget of Goma as a pattern of that of the DRC (Democratic Republic of Congo).

1.3. Objectives

1.3.1. Main Objective

The main goal of this project is to design and investigate the behavior of a grid-connected solar photovoltaic inverter in the Goma power distribution system.

1. 3.2. Specifics Objectives

i) Collect data for present electric energy supplies in the city of Goma.

ii) Design of the (PED) DC/AC converter MPPT grid connected PV.

iii) Evaluate the (PED) DC/AC converter MPPT grid connected PV using MATLAB/Simulink

1.4. Research Questions

Based on this thesis, we will have to answer these different questions:

i) What are the necessities for connecting a Micro-Solar PV device into the grid?

ii) How can REI using the PED *DC/AC converter* MPPT can affect economically and the development of the consumer?

iii) Compared to the conventional power grid, what can the new local device efficiently affect the system

1.5. Scope of the Study

This project is based on the design and analysis of a PV inverter that is connected to the power grid ; it is a novel system that improves efficiency and power quality. The material that will assist us in simulating the system is the MATLAB/Simulink environment.

1.6. Organization of the Work

In Chapter One, we have introduction which has background, problem statement, objectives, and research questions; The Chapter Two has the literature reviews of the problem formulation. The Chapter Three is based on the development of good methodology by referring to the previous method. The Chapter Four is analysis and result of a modern designed PED, the Chapter Five with the Conclusion and Recommendations. Finally, there's a list of Appendices and References.

CHAPTER 2

LITERATURE REVIEW

2.1. Review of the Inverter for Grid Connected Solar

Suresh H. Kala et al, [1] used MATLAB's SIMULINK environment to build a single-phase inverter system connected to the grid. The author uses the output of the solar energy production equipment to inject power into the public grid.

Ersan Kabel et al, [2] offered the layout and evaluation of a single-section micro inverter. For this author, in addition to the preceding one with the MATLAB software in its SIMILINK environment, he analyzes the PV system, which has a minimal variety of semiconductors and has excessive yields, including a few sun irradiations. For its inverter, notwithstanding versions in sun irradiation, the output voltage does now no longer extrude and manifests itself withinside the shape of natural sine waves.

Amir et al [3] presented a detail report of the design and structure of the parameters of HGCI. It is a new type of inverter, which produces PV energy with conditioning of the amount of energy.

Abdelhadi et al [4] supplied the layout and evaluation of a single-segment micro inverter. For this author, in addition to the preceding one with the MATLAB software in its SIMILINK environment, he analyzes the PV system, which has a minimal variety of semiconductors and has excessive yields, including a few sun irradiations. For its inverter, no matter versions in sun irradiation, the output voltage does now no longer extrude and manifests itself withinside the shape of natural sine waves.

Tommaso Caldognetto et al [5] A multimodal control system for interlinking converters integrating microgrids and AC mains was described. For converters that interface DC energy resources with the AC utility grid, applicable standards impose power quality and grid support function criteria.

Ramon Caceres et al [6] Proposes a novel voltage supply inverter known as a boost inverter or boost DC - AC converter. The most crucial feature of the new inverter topology is that it provides an AC output voltage that is greater than the DC input voltage, depending on the duty cycle at the time.

Mohit Bajaj et al [7] offered a complete evaluation of energy high-satisfactory demanding situations with grid integration of renewable DG structures and cutting-edge studies popularity of related mitigation techniques.

Guy Maître et al [8] supplied a DC-AC converter supplied with at the least one transistor whose emitter is hooked up to the bottom via at the least a resistor, and similarly greater a transformer which has a number one winding, a coupling winding and a secondary winding. A coupling capacitor has linked among the coupling winding of the transformer and the bottom of the transistor

Ramon O et al [9] proposed a lift inverter or raise dc–ac converter as a brand-new voltage supply inverter (VSI). The fact that the novel inverter topology creates an ac output voltage greater than the dc entry one, depending on the instant responsibility cycle, is its most notable feature.

Hans Ertl et al [10] offered a unique DC–AC converter for withinside the place of disbursed strength technology structures, e.g., sun strength structures, fuel-molecular strength structures in aggregate with amazing capacitor or battery strength storage.

Ikuwo yamoto et al [11] The usage of a high frequency connection is detailed in the power convention scheme for a UPS (uninterruptible power supply). A high frequency inverter, a high frequency transformer, and a cycloconverter with a brand-new voltage clamper are all included in the proposed UPS. The clamper effectively lowers the conversion system's power deficit. The fabrication of a 10KVA high frequency hyperlink DC/AC converter is described, as well as its loss discounting effect.

Mikihiko Matsui et al [12] established a brand-new strategy for removing such voltage clamp circuits that uses the most effective natural-commutation section perspective manipulates for the cycle converter level rather than PWM. The prototype system's experimental results, which include the software as an AC energetic filter, have also been displayed.

2.2. Research Gap

The electricity tariff has been the subject of research so far. However, no research has been done on inserting a power electronic device (PED) into the grid, either for the country or for Goma. There is currently no standard that defines the network's efficiency and behavior indices and can be used as a baseline for the system and a foundation for developing a good PED with government control. As a result, the city of Goma's energy distribution system was used as a case study in this thesis to examine the efficiency and behavior of the DRC's electricity network in general and Goma in particular. The findings led to the establishment of efficiency and behavior standards for the power distribution firm network by the electricity system authorities.

2.3. Problem Design

Our key issue is with the production unit, connectivity, and the useable part of the power to improve the system's reliability and sustainability. The connectivity of a PV system to the grid is seen in Figure 2.1, with the PED inverter as a critical component.

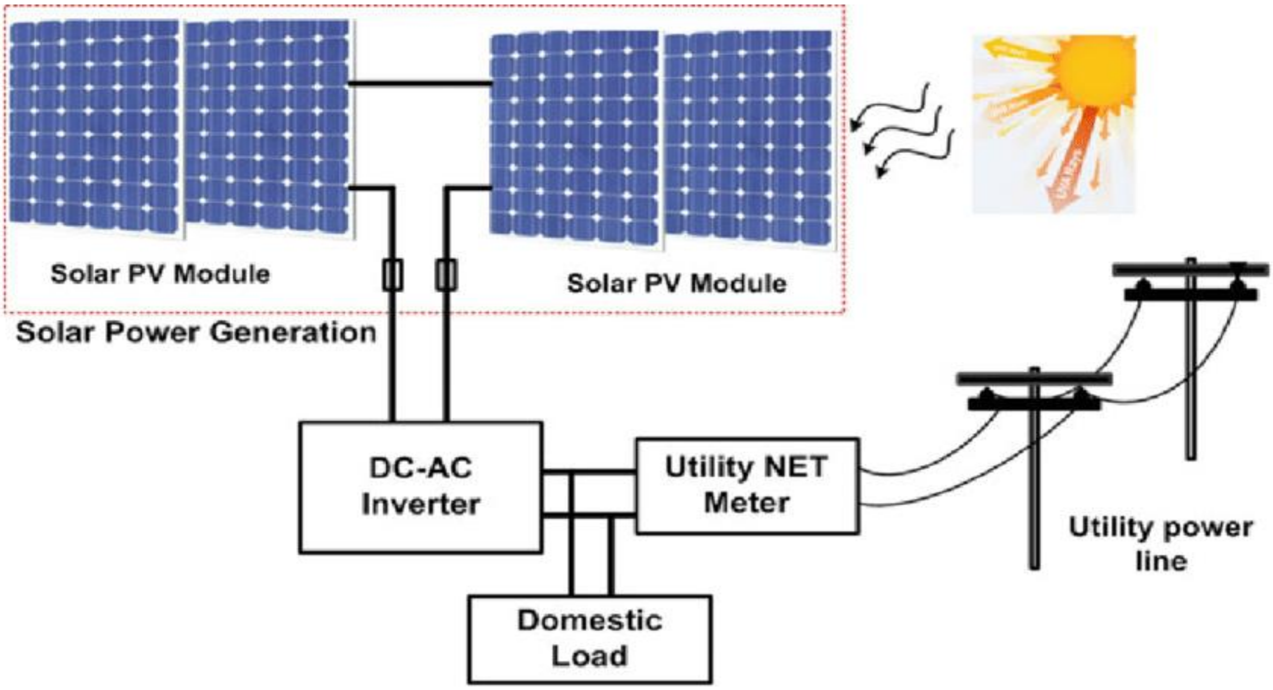

Figure 2.1: Example of a Hybrid DC/AC Micro-grid System

2.4. Block Diagram of the System

The simulation of the suggested system in Simulink is presented in Figure 2.2. The use of a power electronic device that has the Inverter Characteristics Selected has model created SPR due to their performances, efficiency, and capabilities that has yet to be tested. The key differences between them are listed in Table 3.1; this PED is used to link the off-grid solar PV system to the SNEL network.

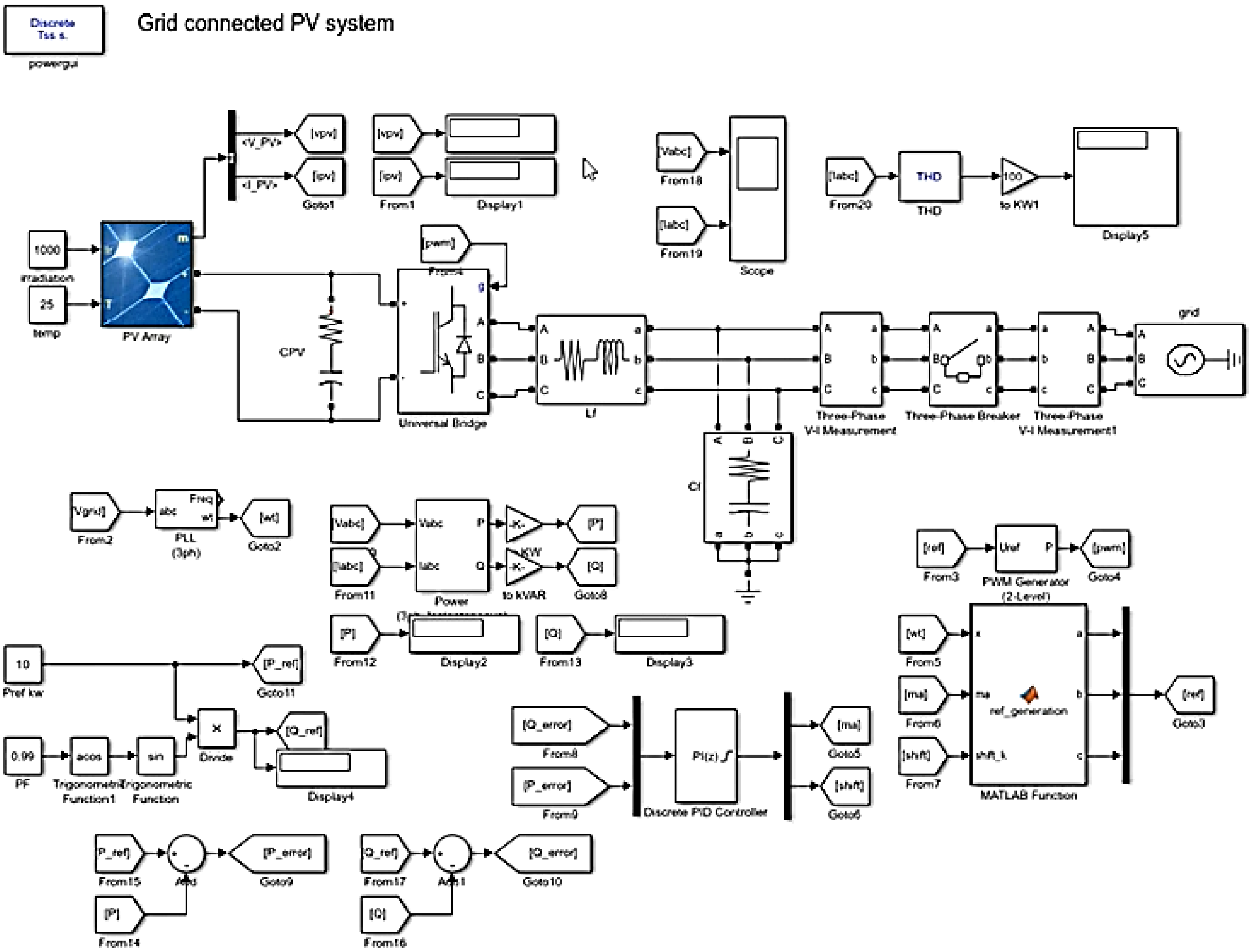

Figure 2.2: Shows a SIMULINK simulation of the proposed system.

2.4.1 Flow Chart of System

2.4.1.1 Maximum Power Point Tracking *(MPPT)*

The output voltage and energy of a photovoltaic cell array are nonlinear, and they are affected by light intensity, ambient temperature, and the load state. The output voltage of a solar cell could be distinguished in a positive range in a positive environment. Photovoltaic cells' output energy reaches its maximum effective value at a positive output voltage value, known as the maximum power point. Maximum power point tracking *(MPPT)* is the process of getting a PV system to track over the maximum power point.

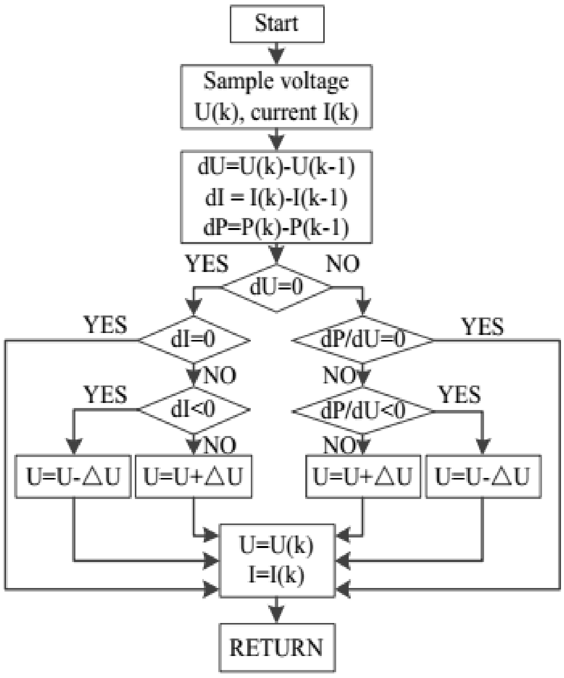

Figure 2.3 Flow Chart of System

Figure 2.3 shows that as the environment changes, the output voltage of the PV cells system e asily tracks the maximum power point, allowing the oscillation phenomenon, which exists clo se to the factor of maximum power point, to progress in a large quantity, as well as the efficie ncy of photovoltaic cells technology power.

2.4.2. Problem Formulation

2.4.2.1. Power Flow Equations and Constraints (PFEC)

Let $P_{lm}(t)$ and $Q_{lm}(t)$ denote the real and reactive power flows from nodes i to j via the link (l, m). respectively (l, m) in the distribution circuit, for each link(l, m).

$$P_{lm}(t) = \sum_{K:(m,n)\in E} P_{mn}(t) + r_{lm}\frac{P_{lm}^2(t)+Q_{lm}^2(t)}{v_l(t)} + p_m^c(t) - p_m^g(t) \quad (2.1)$$

$$Q_{lm}(t) = \sum_{K:(m,n)\in E} Q_{mn}(t) + x_{lm}\frac{P_{lm}^2(t)+Q_{lm}^2(t)}{v_l(t)} + q_m^c(t) - q_m^g(t) \quad (2.2)$$

$$v_j(t) = v_i(t) - 2\left(r_{lm}P_{lm}(t) + x_{lm}Q_{lm}(t)\right) + (r_{lm}^2 + x_{lm}^2)\frac{P_{lm}^2(t)+Q_{lm}^2(t)}{v_l(t)} \quad (2.3)$$

2.4.2.2. Switched Controller Model (SCM)

In our VVC system, we consider switching shunt capacitors and substation Under Load Tap Changer (ULTC). While shunt capacitors are turned on, they generate reactive strength. Because shunt capacitor settings are changed on a timeline for each T, we define this as:

$$q_l^g(t) = C_i(T)q_i \qquad \forall i \in V_c, t \in T \tag{2.4}$$

where $C_i(T) \in \{0,1\}$ is the period T switching control. That is, when the capacitor at node I is turned on, it generates q reactive power and when it is turned off, it generates no reactive power. The voltage $V_0(T)$ on the substation bus is regulated by the substation ULTC in discrete steps, like distinct faucet levels. It is also managed over a long period of time.

2.4.2.3. Inverter Model (IM)

Nodes $i \in V\backslash V_c$ have inverters that are controlled at the rapid timeframe t in addition to the slow timescale control. For our purposes, we utilize the inverter model; the major conclusion is that the magnitude of the reactive power created at an inverter, $q_i^g(t)$,is upper bounded by a quantity that depends on the real power generated at node I for all $i \in V\backslash V_c$

$$|q_i^g(t)| \leq q_i(t) \tag{2.5}$$

For each t, the upper bound $q_i(t)$= $\sqrt{S_l^2 - (P_l^g(\mathrm{t}))^2}$ is assumed to be given. S i is the PV panel's rated apparent power capacity at bus I and $P_l^g(\mathrm{t})$ denotes the real power generated at time t.

2.4.3. Optimization Problem Formulation

2.4.3.1. Voltage Limits Constraints

$$V_{min} \leq V_{minlik} \leq V_{max} \tag{2.6}$$

$$\forall h \in H, l \in, k \in K \tag{2.7}$$

where V_{min} and V_{max} are the lowest and upper bounds for bus voltage magnitudes, respectively.

2.4.3.2. Line Ampacity Constraints (lAC)

$$I_{mhis} \leq I_{s\,max}$$

$$\forall h \in H, l \in I, s \in L$$

Where I_{mhis}distribution network segment is line current and $I_{s\,max}$ is the current-carrying capability of the distribution network section.

2.4.3.3. Modeling of PV Modules (MPVM)

The active power profiles corresponding to the solar irradiance and ambient temperature data in use are generated using the active power generation of a PV module.

$$Tm_t = Ta_t + \frac{NOT-20}{800} * Girr_t \quad (2.8)$$

$$Isc_t = \left(Isc_{nc} + K_I * (Tm_t - 25)\right) * \frac{Girr_t}{1000} \quad (2.9)$$

$$Voc_t = \left(Voc_{nc} + K_V * (Tm_t - 25)\right) \quad (2.10)$$

$$FF = \frac{V_{MPP} * I_{MPP}}{Voc_{nc} * Isc_{nc}} \quad (2.11)$$

$$PVmodule_t = Voc_t * Isc_t * FF \quad (2.12)$$

where at time t, Tm_t is the PV module operating temperature, Ta_t is the ambient temperature, NOT is the module nominal operating temperature, $Girr_t$ is the global irradiance, Isc_t is the module short-circuit current, Isc_{nc} is the short-circuit current under nominal conditions, K_I is a current temperature coefficient, Voc_t is the module opencircuit voltage, Voc_{nc} is the module open-circuit voltage under nominal conditions, K_V is a voltage temperature coefficient, V_{MPP} and I_{MPP} are respectively the module voltage and current at most strength factor situations and $PVmodule_t$is the module output strength. For a given set up site (distribution community geographical region), it is assumed that PV turbine owners select modules with the strongest manufacturing characteristics on the given site (features of module parameters and location climatic conditions), and thus PV module characteristics are assumed to be the same in all buses on this study.

2.4.3.4. PV Power Generation Probabilistic Modeling

according to (2.11). For each hour h ∈ H, three probability points for solar irradiance (based on classes), $Girr_{hx}$,1 ≤ x ≤ 3; and three probability points for ambient temperature (based on normal distribution), Ta_{hy},1 ≤ y ≤ 3; are established. This modeling method yields a set of nine possible PV module output power levels for a given hour h: $Pmodule_{hi}$,1 ≤ i ≤ 9; and nine related probability ies: $Prob_{hi}$ (Pmodule),1 ≤ i ≤ 9. According to the substitution of each feasible combination of $Girr_{hx}$ andTa_{hy},, the set of PV module possible output power levels for hour h is produced (2.11). What are the necessities for connecting a Micro-Solar PV device into the grid? The corresponding se t of possibilities is acquired from the multiplications of the 2 possibilities corresponding to $Girr_{hx}$ and Ta_{hy} in every combination, (2.12). $Girr_{hx}$ and

Ta_{hy} are assumed uncorrelated. Every month is consequently represented with the aid of using twenty-4 hourly units of PV output energy possibilities; every set is of 9 hourly possibilities.

$$G = \{ Voc(Girr_{hx}, Ta_{hy}) * Isc(Girr_{hx}, Ta_{hy}) * FF \mid x, y \in \{1,2,3\}\} \tag{2.13}$$

$$U = \{Prob(Girr_{hx}) * Prob(Ta_{hy}) \mid x, y \in \{1,2,3\}\} \tag{2.14}$$

2.4.4. Line Model Problem (LMP)

2.4.4.1. Network Model (NM)

Constant power (PQ) injection of inverter-based renewable resources and PQ consumption of network loads are two sources of uncertainty discussed. It is also believed that the various scenarios for distributed generation and loads may be effectively described by a finite collection of scenarios, indexed by l ∈L= {1..., L}, each of which occurs with probability π^l. The following scenario-dependent scaling factor $k^l_{n,\phi}$ of the nominal PQ consumption $s^l_{ln,\phi}$ is used to model load uncertainty:

$$s^l_{kn,\phi} = k^l_{n,\phi} s^l_{kn,\phi} \tag{2.15}$$

Let s^l_g, s_l , v^l , and i^l assemble their counterparts on all non-slack buses and phases

2.4.4.2. Limits online Thermal Loss

The linear approximate equation for thermal loss P^k_{nm} on edge (n,m) ∈ E per scenario κ ∈K is proved in this thesis.

$$P\wedge^l_{mn} + 1^T \mathrm{Re}[\Gamma^l_{mn}(V^l_m - V^l_m) + \Phi^l_{mn}(V^l_m - V^l_m) * + \Gamma^k_{nm}(V^k_n - V^l_n) + \Phi^l_{nm}(V^l_n - V^l_n) *] \tag{2.16}$$

where V_n and V_m Collect v's entries for buses n and m, and v's entries for buses n and m, respectively.

$$P\wedge^l_{mn} = \mathrm{Re}\left[V\wedge^T_m\left(\left[Y^{(m)}_{mn}\right]^l V\wedge^k_m - \left[Y^{(n)}_{mn}\right]^l V\wedge^k_n\right)^* + V\wedge^T_n\left(\left[Y^{(n)}_{nm}\right]^l V\wedge^l_n - \left[Y^{(m)}_{nm}\right]^l V\wedge^l_m\right)^*\right] \tag{2.17}$$

$$\Gamma^l_{mn} = diag\left(\left[Y^{(m)}_{mn}\right]^l V\wedge^l_m - \left[Y^{(n)}_{mn}\right]^l V\wedge^l_n\right)^* \tag{2.18}$$

$$\Phi_{nm}^{l} = diag(V_{m}^{l})\left(\left[Y_{nm}^{(m)}\right]^{l}\right)^{*} - diag(V_{n}^{l})\left(\left[Y_{nm}^{(m)}\right]^{l}\right)^{*} \quad (2.19)$$

where admittance matrices $\left[Y_{mn}^{(m)}\right]^{l}$, $\left[Y_{mn}^{(n)}\right]^{l}$, $\left[Y_{nm}^{(n)}\right]^{l}$, $\left[Y_{nm}^{(m)}\right]^{l} \in \mathbb{C}^{3x3}$ For transmission lines, transformers, and step-voltage regulators, $\mathbb{C}^{3x3}$ is used. Limits on thermal loss are then simply enforced utilizing

$$P_{mn}^{l} \leq P_{mn}^{max}, (\mathrm{m}, \mathrm{n}) \in \mathcal{E}. \quad (2.20)$$

2.4.5. Regulation of Voltage

A second-order cone constraint enforces the upper-limit on voltage magnitudes, as follows: |vlm, φ|≤ vmax The lower limit on voltage magnitudes, on the other hand, is not convex. We're looking for a way to verify the lower limit restriction so that we can construct a computationally tractable optimization problem. To begin, note that |vlm, φ| ≥ |ˆ vlm, φ|−|vlm,φ|.

2.5 Chapter Conclusion

In this chapter we've got mentioned approximately the literature evaluate wherein we've got handed via on distinctive paintings finished via way of means of different authors. We have additionally reviewed the theories on historical past wherein a few crucial factors had been discovered such as: hassle design, hassle formulation, switched controller model, inverter model, PV module modeling.

CHAPTER 3

METHODOLOGY

3.1. Previous Method

The previous method was focalized to improve the efficiency of the system, but unfornatly they did not have any feedback circuit for protection, which affected the system.

3.1.1. LV Method [13]

The Ratio is solved for all PV connection buses in the case of MV linked PV facilities. Unfortunately, this technology causes inverter current fluctuations, which impair the distribution network.

3.1.2. Hybrid Method [14]

This technique combines each the time-area simulation and lyapunov technique. Firstly, with the aid of using the use of time-area simulation we acquired the device variable curve, secondly in step with the trajectory the electricity of the device is finding. The hybrid technique must preserve the stableness evaluation of energy device. this technique wishes greater research due to its weak point for the energy-converter-grid.

3.1.3. Conventional Droop Control [15]

The classic hunch technique is based on the idea that the frequency and amplitude of the inverter voltage may be utilized to control both active and passive power flows.

3.1.4. Virtual Output impedance [16]

The digital output impedance loop can be used to recover the inverter's output impedance, which defines the hunch manipulate approach and influences power-sharing accuracy. The effect of line-impedance unbalance can be mitigated by properly laying out the output impedance.

3.1.5. Implementation of Droop Control [17]

The control strategy is presented for a micro-grid that is only powered by inverters. These controllers work in tandem to regulate the micro grid's voltage and frequency collectively. The frequency of the micro-grid varies when running in islanded mode, and none of the DG devices can put the system's bottom frequency into action. The frequency variances can be limited by incorporating a frequency-slump function that uses the micro grid frequency as a verbal exchange medium to dynamically stabilize the islanded micro grid's actual energy era.

3.2. Proposed Method

3.2.1. Perturb and Observe (P&O) MPPT Algorithm [18]

By figuring out present machine distribution and their deficit, we can begin to examine the electricity high-satisfactory and the way it may be advanced withinside the machine the usage of inverter. We will keep in mind a few preceding works as crucial enter to behavior the study. We will Designed, analyzed, and simulated the usage of software (MATLAB/Simulink) for you to see the machine performance.

3.2.2. Inverter Control Method PWM Power Type (ICMPPT)

To conduct synchronous transformation, it comprises of two bridge circuits with two opposite diodes. It uses a discontinuous current manipulating approach to raise or lower the output voltage of the PV, resulting in the desired power, which is managed using the PWM conversion modulation rate. For one thing, it has nothing to do with the transport voltage of PV cells; it can output any amount of power to the system or load; and, for another, the cost of power factor is high since the control signal is connected to the system. Finally, the circuit concept is low-cost and straightforward. The most important advantage of a power type PWM inverter is that it can set a power standard for the system. To connect the PV system to the grid, first set the enter sign Ui and the grid voltage to the same phase, then Ui force PWM power type inverter to get the output voltage.

3.2.3. PWM Inverter Control Techniques Have Been Improved (PICTI)

Control mechanism for PWM inverters has been improved (IPICM) The two opposite diodes used in electricity type PWM are deleted in the stepped forward PWM inverter control mechanism. And because the inverter's force voltage section is generally based entirely on the grid voltage section, the output power factor can be stored at a high level. The stepped forward PWM inverter control device also uses the outer loop to regulate voltage and the internal loop to regulate current-day, which is the same as the voltage supply inverter control, after which it tracks the most power factor after the output current-day transforms to an in-shape type, ensuring the battery's maximum power output. As a result, the inverter model is less difficult than the power type PWM and ensures power output stability. The subsequent mode is recognized by the stepped forward PWM inverter circuit. For starters, paintings can be used as an AC switch. This stepped forward type PWM inverter control technique followed the remoted transformer to allow the weight to obtain the correct voltage, which is a critical function in the AC to DC conversion process.

3.3 The MATLAB / Simulink Tool [20]

MATLAB is part of a suite of tools that work together. The environment also includes optional modules that are integrated into the set, in addition to the MATLAB calculating kernel. SIMULINK is a platform for multi-domain dynamic system simulation and modeling. It includes a graphical environment as well as a set of libraries with modeling blocks for precise design, simulation, implementation, and control of communications and signal processing systems.

3.4 Case Study

A grid-connected solar inverter is recommended in this study to increase system efficiency and benefit consumers. It's crucial to remember that solar energy is initially costly, but it's also environmentally good. We need to put the system in place in Goma/DRC, synchronize the inverter's output voltage with the grid voltage, and increase the system's efficiency.

3.4.1. Goma Electricity Demand Estimation

The product of the connected load and the sufficient demand factor determines a consumer's maximum demand. Furthermore, the total demand for the transformer is the sum of all total demands divided by the number of users. The actual total Goma electricity demand is shown in MW in Figure 3.1.

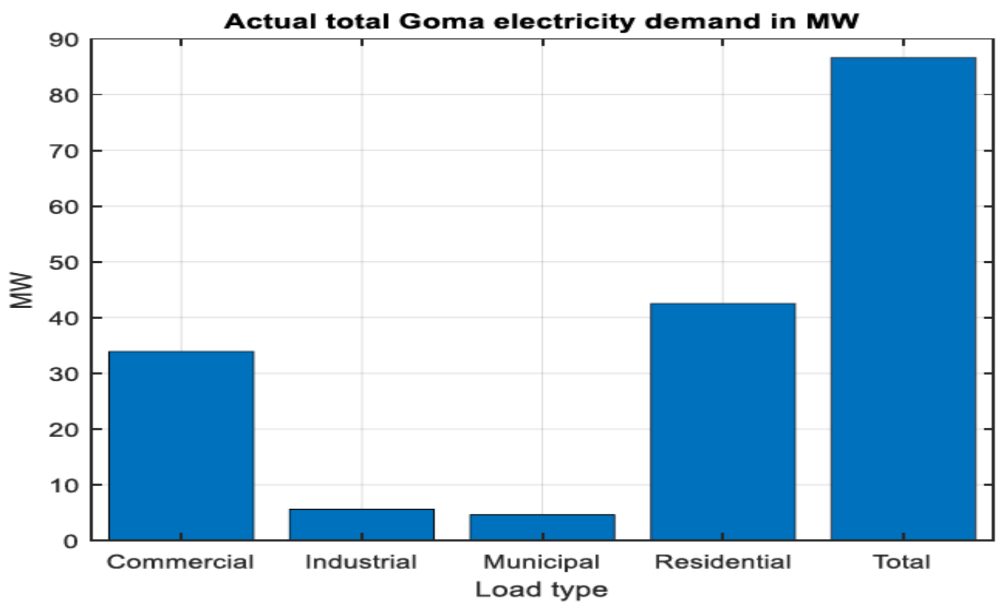

Figure 3.1 Total Goma Electricity Demand in Megawatts (MW)

3.4.2. Characteristic of the Grid Study

3.4.2.1. SNEL Network

It is the city's primary provider, covering 18 % of the city's electricity access price. From Ruzizi to Goma substation, a 70 kV transmission line is used. The metropolis's distribution machine has a primary voltage of 15 kV and 6.6 kV, and its miles stepped all the way down to 380 and 220 volts for patrons. It has one substation with a mounted energy of two transformers functioning as a replacement for 2X10 MVA /110-70 kV/15kV characteristics and one thermal energy plant with a capacity of 1.1 MVA that is no longer in use due to its high operating costs. It has a radial structure, as shown in Figure 3.2, and five feeds.

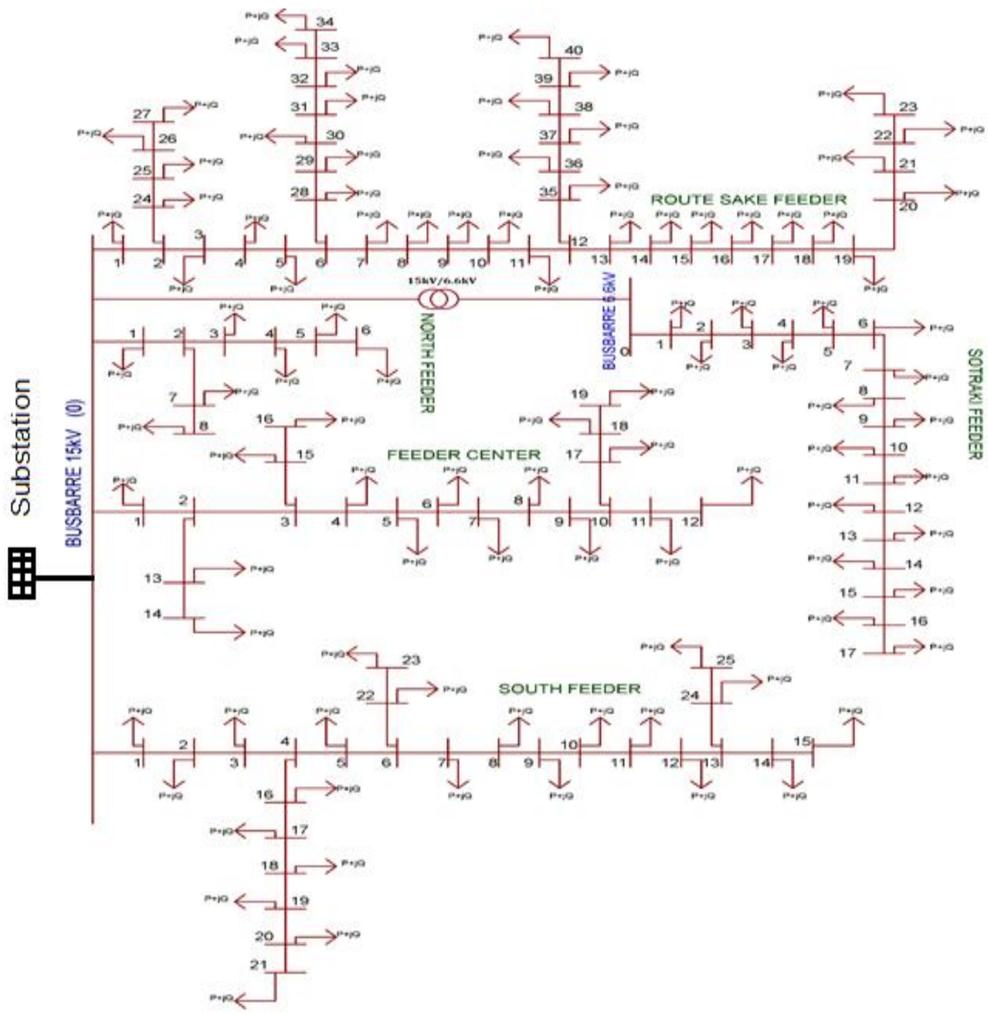

Figure 3.2: Overview of SNEL Network

The Table 3.1 describes numerous energy transformers, the entire mounted potential for every feeder in addition to conductor size.

Table 3.1: SNEL feeder's data

Name of Feeders	Total number of distribution transformer	Total capacity of distribution transformer (kVA)	Voltage rate (kV)	Conductor Size
South feeder (L1)	31	13 250	15	AAC 50mm^2
Centre feeder (L2)	17	7 875		
North feeder (L3)	7	3 970		
Route Sake feeder (L4)	41	16 575		
Sotraki feeder (L5)	19	8 050	6.6	

3.4.3. Power Evaluation

The Goma Energy Total Power Evaluation is shown in Table 3.2. We propose distributed solar generation for each feeder based on the difference between installed capacity and average power transmitted through transmission lines, as shown in Table 3.2.

Table 3.2: Power Evaluation

Lines	Total installed capacity [MVA]	Average transmitted power [MVA]	Power Not served [MVA]
L1	13.25	3.075	10.175
L2	7.875	1.445	6.43
L3	3.97	2.703	1.267
L4	16.575	2.982	13.593
L5	8.05	1.62	6.43
Total	**49.72**	**11.827**	**37.893**

The capacity of the powerplant, the area, the number of PV modules required, the inverter capacity, and the converter size of each feeder are all listed in Table 3.2.

3.4.4. Meteorological Data and Irradiance of the Site Selected

Our study is the preliminary draft, the data used do not reflect the chosen site where the photovoltaic plant will be installed in Goma since our idea is that in most cases the photovoltaic installation be placed on the roof as in the case schools to maximize space. The meteorological data used corresponds to Goma in general and is obtained from Retscreen Software. The Figure 3.3 shows year the situation of climate data in Goma.

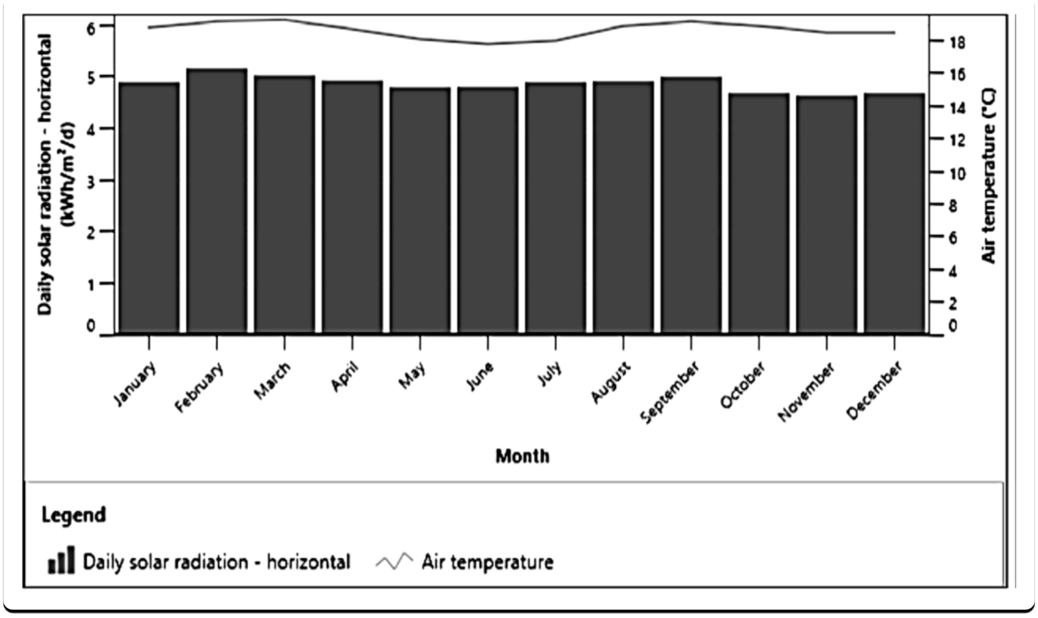

Figure 3.3: Climate data of Goma [23]

The city of Goma is in a wholly excessively insolated area, with radiation tiers ranging between 4.90kWh/m2/day, making photovoltaic and sun heating constructions possible during the site. The Goma Monthly Solar Insolation is shown in Table 3.3.

Table 3.3: Goma Monthly Solar Insolation Goma Monthly Solar insolation

Months	Solar irradiance($kWh/m2$)
January	4.9
February	5.27
March	5.03
April	4.96
May	4.80
June	4.81
July	4.90
August	4.92
September	5.10
October	4.69
November	4.64
December	4.79

The annual average insolation is 4.90 kWh/m^2.

It may be observed that the penetration of sun structures may be very low in comparison to the dimensions of the location, in addition to the supply of this electricity resource. Since our observe is the initial project, the statistics used do now no longer mirror the correct web page in which the photovoltaic electricity plant goes to be installed. The statistics meteorological used corresponds to Goma in standard and is acquired from Retscreen Software. From the Figure 3.4 we discover that the day-by-day common sunshine hour of Goma is 5.5h.

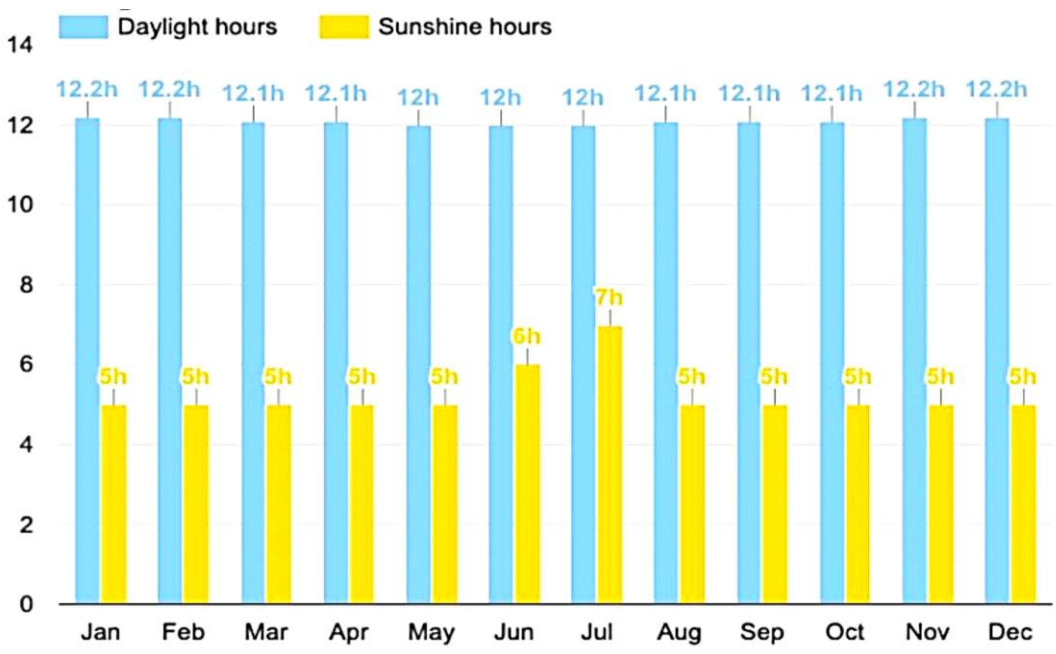

Figure 3.4: Sun Hours Average of Goma

The Goma irradiance may be calculated through understanding its common sun insolation and its common day by day vivid sunshine hours. Using the statistics of top sunshine of Goma metropolis is 5.5h proven within the Figure 3.4, the irradiance of Goma gives:

$$Irradiance = \frac{\text{Average Insolation}}{average\ daily\ bright\ sunshinr\ hours} \quad (4.1)$$

From the equation 4.1, we get:

$Irradiance\ 891W/m^2$

3.4.5. Module photovoltaic

A photovoltaic module is a key component of a solar system that converts direct current power from sunshine. Photovoltaic modules can be connected in series or parallel to provide the voltage and current that a system demands. There are four varieties of solar PV cells, which are single crystalline or monocrystalline, multi-, or poly-crystalline, thin film, and amorphous silicon, based on the increasing need for solar power, which has led to new technologies being introduced and current ones being improved. Let's be clear: mono-crystalline and multi-crystalline silicon are also known as single-crystalline and poly-crystalline silicon, respectively, as shown in Figure 3.4.

Table 3.4: Different Types of Solar Cells' Efficiency

Cell type	Efficiency [%]	Acronym
Mono-crystalline or single-crystalline silicon	12-18	Mono-c-Si
Multi-crystalline or poly-crystalline silicon	12-18	Poly-c-Si
Thin film	8-10	TF-Si
Amorphous Silicon	6-8	a-Si

3.4.5.1. Characteristics of a PV Module Selected

Based on the existing solar photovoltaic power plant for our project in Goma, we select “1SOLTEC-215-P” as a photovoltaic module model of polycrystalline technology, manufactured by “1SOLTE” characteristics shown in Figure 3.5.

Table 3.5: Characteristics of a PV Module Selected

Manufacturer	1SOLTEC
PV Model	1STH-215-P
Dimensions	1626.0 × 964.0 × 46.0mm (38.0 × 64.0 × 1.8 inch)
Weight	20.0Kg (44.1 lbs)
Maximum open circuit voltage V_{oc} (V)	36.3
Maximum short circuit	7.84A
Peak power	215W
Module efficiency	13.7%
Cell Type	Polycrystalline Cell
Cell Size(mm)	156 × 156
Cells	6 × 10
Fill Factor	75.5%
Operating Temperature	-40.0ºC to 85.0ºC

3.4.5.2. Solar PV System Sizing

Based on the reasons for power outages to customers, it is proven within the work that for the aggregate reasons, 76% are due to losses of electricity produced leading to losing the terrible efficiency of the network. Therefore, to improve its efficiency, the main response proposed is to design and analyze an inverter, on this thesis we use an acquired technology for solar electricity for each conductor by relying on the distinction between the mounted capacity and common electricity transmitted via transmission traces as better defined at the Figure 3.5.DC Equivalent circuit

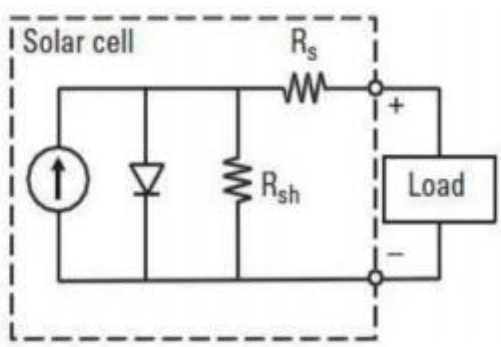

Figure 3.5 Equivalent Circuit in DC

The photovoltaic cell output voltage is essentially dictated by the photocurrent, which is mostly driven by load current and is dependent on the amount of solar irradiation available during operation. Solar Panel I-V and P-V Characteristics Typical I-V Characteristics of a Solar Panel are shown in Figure 3.6.

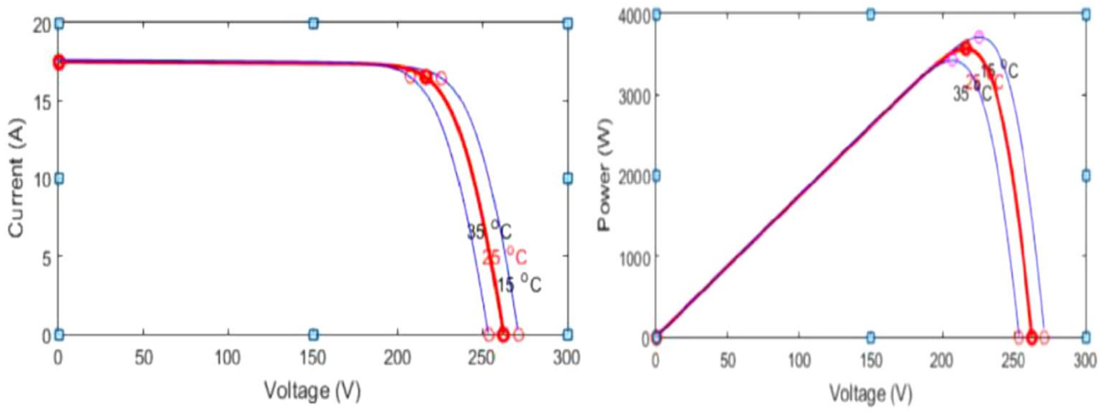

Figure 3.6 Solar Panel I-V and P-V Characteristics Typical I-V Characteristics of a Solar Panel

3.4.6. Inverter for Solar

The yield and legal constraints that inverters must meet in any interconnected grid installation are yield constraints and legal constraints. The capability, the density of the power, the cost of installation, and the minimization of leakage current are all yield requirements. Isolation by galvanic, detection of anti-islanding, and other technical codes are among the regulatory requirements. Solar inverters can be implemented in a variety of topologies, which can include how photovoltaic modules are connected to the inverter as well as their potential applications. We have Central inverters, String inverters, Multi string inverters, Module integrated inverters, and Mini central inverters because of this. It is possible to install a photovoltaic system throughout the city. In the following section, we will use MATLAB to simulate the sizing of a PED device (inverter) photovoltaic power system to fulfill the electricity demand in Goma. The Inverter Characteristics Selected has model made SPR owing to their performances, efficiency, and capability still to be tested. The main characteristics of each of them are listed in Table 3.1 below.

Table 3.6: Characteristics of Inverter Selected

High efficiency inverters	Electrical specification
Manufacturer	SPR
Model	SPR-4000X
Maximum AC power output	4000W
AC output voltage (nominal)	240VAC
AC Voltage range	211-264VAC
AC frequency (nominal)	60HZ
AC frequency range	59.3-60.5HZ
Maximum continuous output current	16.7A
Current THD	<3%
Power factor	>0.9
DC input voltage range	195-600VDC
Max DC Current	22.Adc
Peak inverter efficiency	95.7%
CEC Efficiency	95.0%
Nighttime power consumption	<1W
Output overcurrent protection	25A
GROUNDING	POSITIVE GROUND

3.4.7. Factors Affecting Electricity Demand

Several influencing elements, such as population, GDP, electricity pricing, economic structure, urbanization, and lifestyles, can be seen as a causal function of electricity consumption. The overall power consumption is calculated by adding together the demands of primary, secondary, and tertiary industries, as well as households.

3.4.8. Each inverter's total output power ($\boldsymbol{Pinv, out}$)

Because one inverter is coupled to one PV block in our study topology, this one is dependent on the inverter parameters. The following expression is used to calculate the output power of each inverter:

$P_{inv}, O = \frac{\eta_{inv}}{100} * P_{inv}$ (3,1)

Where: ηinv [%] is the solar block output power, and Pin is the inverter power conversion efficiency.

3.4.9. Injected Power PV Plant into the Grid (*PPLANT*)

The step-up transformer losses and the AC cable losses are used to calculate the solar power plant injected into the electric grid. As a result, the following equation is utilized in this calculation:

$P_{PLANT}, O = \frac{\eta_T}{100} * \frac{\eta_{cable}}{100} P_{inv}, 0 * 10^{-6} * N_i$ (3.2)

Where: ηT [%] is the interconnection transformer efficiency. its value is set at 99%; $\eta cable$ [%] is the AC connections cable efficiency. This value is set at 99.5%.

The power that can be put into the grid without power and voltage grid limits is calculated using the P_{PLANT}, result.

3.4.10. Energy Injected into the Grid (*EPLANT*)

Two parameters are involved in estimating the injected energy into the grid, according to the revised literature. It is calculated using the yearly average sunshine hours and the photovoltaic power plant's availability factor for maintenance purposes. The following is the expression used to determine the energy introduced in this step:

$E_{PLANTE} = \frac{E_{EAF}}{100} * P_{PLANTE} * \Delta t$ (3.4)

Where E_{EAF} [%] [percent] is the energy availability factor for solar plants. According to, its value is set at 99.5 %t. Δt=365∗ $Average$ Sunshine Hours [h] is the annual average number of sunshine hours in a year. As of now, the city of Goma has an average of 5.5 hours of sunshine every day.

3.4.11. Specific Energy Grid (SEG)

The ratio among the entire electricity output and the capability set up is taken because the yield of a photovoltaic electricity plant. This remaining is taken into consideration an overall performance parameter and it may be used to evaluate various photovoltaic producing electricity. Besides, it expresses the hour's range this is required for the photovoltaic array to paintings at its rated electricity even as generating the equal electricity.

$Yield_{sp} = \frac{E_{TOTAL}}{P_{PLANTE,nom}}$ (3.5)

3.4.12. Performance Ratio ($\boldsymbol{PR}$)

The performance ratio (PR) is a metric that can be used to evaluate plant performance and behavior. It is a parameter that can be used to compare different solar systems regardless of their generating capacity. As a result, it is regarded as a quality indicator. The time under consideration is one year, and the parameter is calculated using the following formula:

$$\mathrm{PR}(\%) = \frac{\mathrm{SE}_{GRID}}{\mathrm{RY}} * 100 \quad (3.6)$$

WhereSE_{GRID} is represented in [MWh] and represents the photovoltaic power plant's total annual generated energy, and *RY* is the reference yield in hours. The following formula can be used to express the reference yield *RY*:

$$\mathrm{RY} = \frac{H}{\mathrm{G}_T} * 100 \quad (3.7)$$

G_T is the PV reference irradiance in (the value at STC, which is 1000 W/m2), and *H* is the total plane irradiance in. The number of required inverters is calculated using the total power of the charge multiplied by the inverter capacity, with a 30 percent margin of error.

Table 3.7 illustrates that one inverter strand is connected to one PV block, which is why this is dependent on the inverter specs. It was discovered that the amount of photovoltaic power injected into the electric grid is determined by the losses of the step-up transformer and the losses of the AC line. We computed the injected energy into the grid using two parameters. It is calculated using the yearly average sunshine hours and the photovoltaic power plant's availability factor for maintenance purposes. This is a performance metric that can be used to compare different solar generating capacities.

Table 3.7: Total Amount of the Inverter Sizing

Lines	Number of inverters	$\mathrm{P_{inv}}, O$ [MW]	P_{PLANT}, O [MW]	E_{PLANTE} [MWh]	$\mathrm{Yield_{sp}}$ [KWh/KWP]
L1	55	8.37522	453.7506	906349.808	103576.917
L2	80	5.2920	417.0308	833003.384	150638.971
L3	43	1.0427	44.1658	88219.5293	80963.5738
L4	102	11.1873	1124.1054	2245358.38	192075.139
L5	51	5.2920	265.8571	531039.588	96032.3317

3.5. Mapping Method to the Problem

The major goal of this project is to start by examining the middle of our work, then investigate the feasibility of connecting a converter to the distribution network, and ultimately increase the system's efficiency. The prototype's implementation will be done in MATLAB.

3.6. Conceptual Framework

Table 3.8. Conceptual Structure of Research Methodology

<table>
<tr><td>Research methodology</td><td>Data Collection based on documentary, technique Environmental, social, economic, and technical aspects in Goma</td></tr>
<tr><td>Field data collection
Select of the inverter topologies
Collect of information concerning lifestyles condition in Goma
Site choice primarily based totally on a bodily statement and taking account of a few characteristics</td><td>Internet data collection
Documentations posted at the net like this (evaluation of the literature)
Solar irradiance primarily based totally on Metrological on-line records
Published works
Government document records in DRC, and identical society which include OVG, PNUD</td></tr>
<tr><td colspan="2">Result
Design and Sizing of the System
Simulation using MATLAB/Simulink software
Analysis of the system
Discussion of the Result and Conclusion</td></tr>
</table>

3.7. Chapter Conclusion

This chapter focused on data collecting and the strategies for analyzing the results obtained once they were processed. An enhanced incremental conductance control technique was presented based on some recent studies on the incremental conductance method, which can track maximum power point quickly and reliably. The oscillation phenomenon, which occurs at the maximum power point, has been greatly improved, as has the efficiency of photovoltaic cells in producing electricity. Meteorological data, load characteristics, total output power of inverters, and energy injected into the grid were among the data given.

CHAPTER 4

RESULT AND ANALYSIS

This thesis established a new inverter model that can quickly and precisely track the maximum around the highest power point, resulting in increased PV power generation efficiency. While the former DC/DC converter achieves maximum power tracking control, the latter inverter preserves DC bus voltage stability and executes grid connect. The system can be simply matched because both are connected via the intermediate DC bus. The control algorithm has a high execution rate and is extremely stable. The system is stable and operates well, according to the simulation findings. The DC bus voltage is around 450V, and the PV array's output power is at its maximum, resulting in an excellent sinusoidal output wave. The simulation achieved the expected results, according to the findings. Figure 4.1 depicts the PV array model of the system.

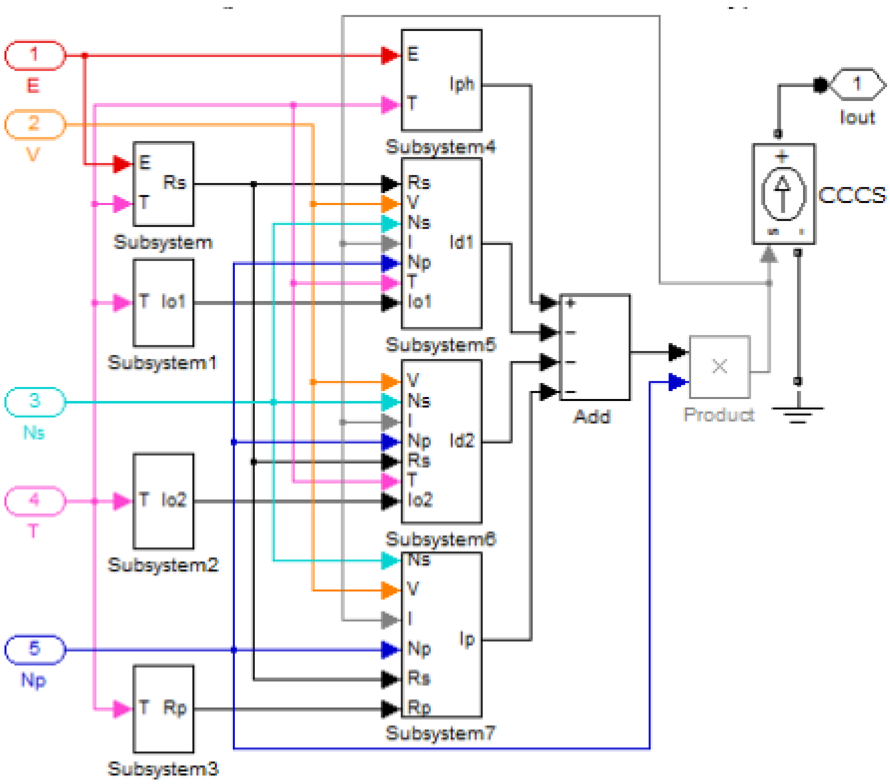

Figure 4.1 Model of a PV array

The DC-AC converter employs double PI control. The outer loop regulates output current stability while the inner loop ensures DC bus voltage stability. The control flow chart is shown in Figure 4.2.

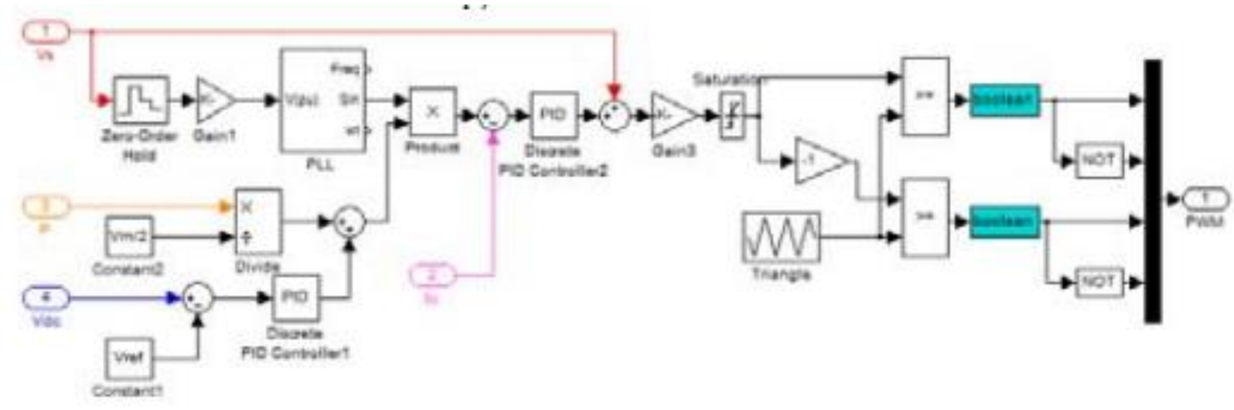

Figure 4.2. DC-AC control flowchart

4.1. **PV grid-related Inverter Methods Simulation Results**

500 PV cells in series and 1000 in parallel, at 300K, mild depth 1000W / m2, grid voltage 220V, 50Hz, intermediate DC bus voltage 450V, simulation time 0.4s, PV array version for simulation results. Figure 4.3 depicts the PV grid-connected inverter variant. Methods 500 PV cells in collection and 1000 in parallel, under the environment temperature of 300K, mild depth 1000W / m2, the grid voltage 220V, 50Hz, intermediate DC bus voltage 450V, the simulation time is 0.4s, use the PV array version for simulation outcomes. The PV grid-connected inverter version is as shown in Figure 4.3.

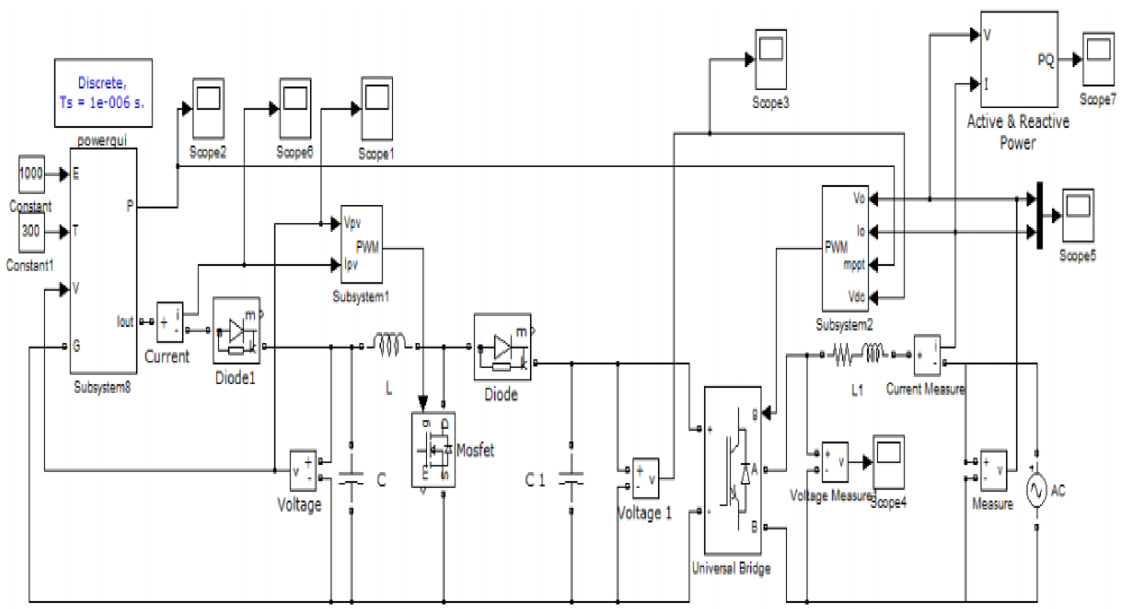

Figure 4.3 Photovoltaic Inventer Simulation Model

4.1.1. The former DC/DC converter

Figure 4.4 shows the waveforms of the preceding DC/DC converter's output voltage, output current, and output energy. On the highest point, the output voltage is kept constant at 180V, the output current is kept constant at 15A, and the power is kept constant at 2500W. The PV array output energy is continuously over the maximum power point, as shown in Figure 4.4, confirming the correctness of the maximum power point monitoring modify algorithm.

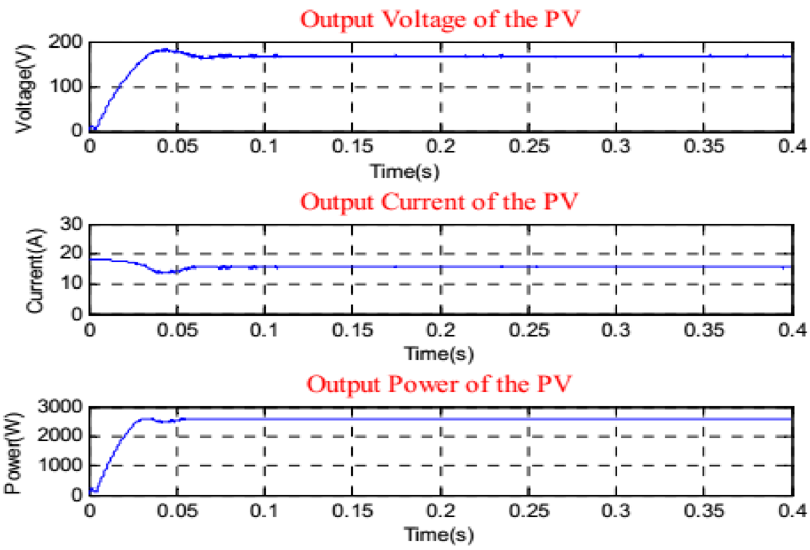

Figure 4.4 The former DC/DC converter

4.1.2 The latter Inverter

Figure 4.5 shows the DC-hyperlink voltage, AC current, and active power of the latter inverter waveforms. The DC-hyperlink voltage is around 450V after system stability, and the AC current is around 10A.

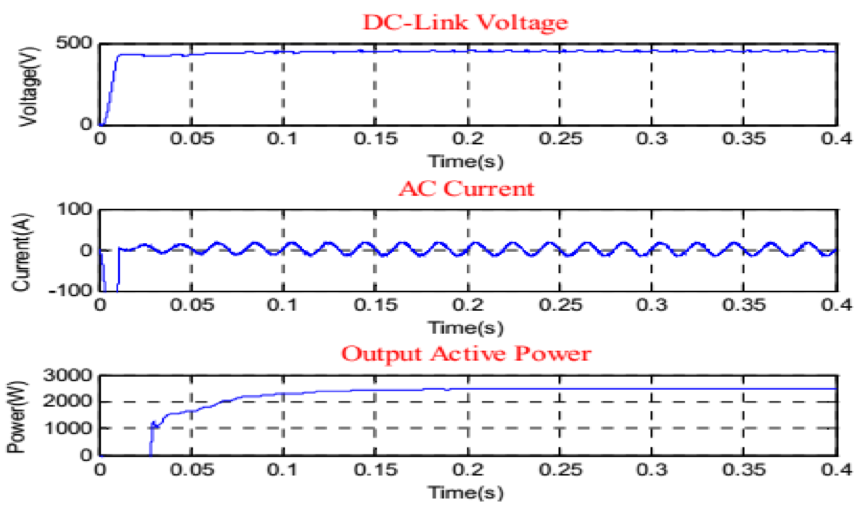

Figure 4.5 The latter Inverter

4.1.3 The Line Facet's Output Voltage and Current

The road facet's output voltage and current are depicted in Figure 4.6. The grid current has the same frequency and section as the grid voltage, the electricity factor is 1, the line facet is the same as the photovoltaic array output power, and the active power is similar to the photovoltaic array output power.

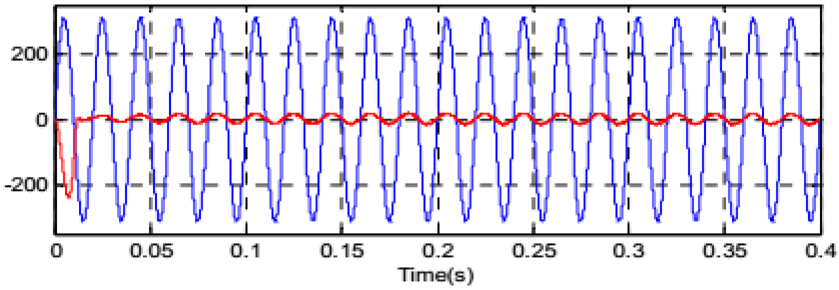

Figure 4.6. The Line side's output voltage and current

4.2. Chapter Conclusion

This financial disaster is based completely on the installed power and the reduced common power via each sup-ply line, a distributed photovoltaic device has been located out and simulated in a PV device to see the behavior of the regulator. Likewise, an assessment of the inverters for all people online further to their amount modified into calculated in step with the power it facilitates. Because of the financial calamity, we were given time to calculate the power to injector on the lines, typical electricity on each line, number of inverters on each line, and the power it facilitates on the present network based entirely on the motives of interruptions and outages. Finally, simulations were completed in MATLAB/Simulink to examine the behavior of the inverter and determine whether they met our expectations using the software program application.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

The major goal of this thesis was to create an inverter, which is a grid-connected combination of a single PV module and a DC-AC inverter. The goal has been to develop a low-cost solution with high reliability, i.e., a long lifespan and high efficiency. The chosen topology's design was also based on theoretical analysis, which was backed up by numerical simulations and observations on the actual prototype. In this thesis, we reply to the modern call for strength in Goma via renewable power assets. We gift renewable power assets and technology withinside the literature defined above. Then, the power situation of Goma changed into offered and where in an evaluation of to be had renewable power assets is detailed. Although it's been located that most effective supply sun power may be used there, given its geographical location. It is placed in a totally excessive uncovered place which makes the implementation of photovoltaic feasible at some stage in the place. We decided Goma's modern strength call for to get a concept of the set-up electricity ability of our proposed technique to sur-mount unmet call for strength. Thus, techniques have been used for the duration of the layout of the parameters: the calculation technique and the software program modeling through MATLAB/Simulink offered previously. However, we layout a centralized photovoltaic electricity deliver plan of the set up photovoltaic electricity to meet the full load of S. For every line we have been capable of calculate the quantity of sun panels, the quantity to be inverted, the electricity to be supported and the floor community of the essential modules received is Various layout parameters of our photovoltaic electricity plant have been received. Regarding the evaluation of MATLAB/Simulink also, are the simulation document above withinside the simulation document indicates the inverters behavior before integration into the grid.

5.2. RECOMMENDATIONS

The power quarter in DR Congo has been liberalized because 2014 pushing the personal quarter to paintings on this area. To set up a actual and possible standard, a have a look at need to be carried out. Therefore, the prevailing paintings carried out this have a look at withinside the metropolis of Goma and taken care of out the conduct of the inverter connecting to the grid that is our focal point. On the idea of the end result obtained, we carried out our targets due to the fact we specifically fulfill the actual call for power with the aid of using presenting the SNEL community with the aid of using energy coming right here from the sun panels way to the PED (inverter), we mitigate the greenhouse impact way to the quantity produced with the aid of using renewable energy as It is said that power from renewable assets is clean, secure and accessible. Though, to the policymakers, I advise as follow:

• The use of smart manages withinside the distribution gadget for the development to always look the conduct of the gadget.

• Regulate the frequency of interruptions in keeping with the extent of the electric community and the period of interruptions contemplating the present-day situation.

• Increase studies in those fields, in order that the concern of positive limitations to renewable energies withinside the destiny is limited.

• Provide software program or application that may be utilized by faraway tracking and inverters.

• To SNEL in DR Congo in fashionable and in Goma in particular, to be open to new generation and to suppose greater approximately interconnection for proper performance.

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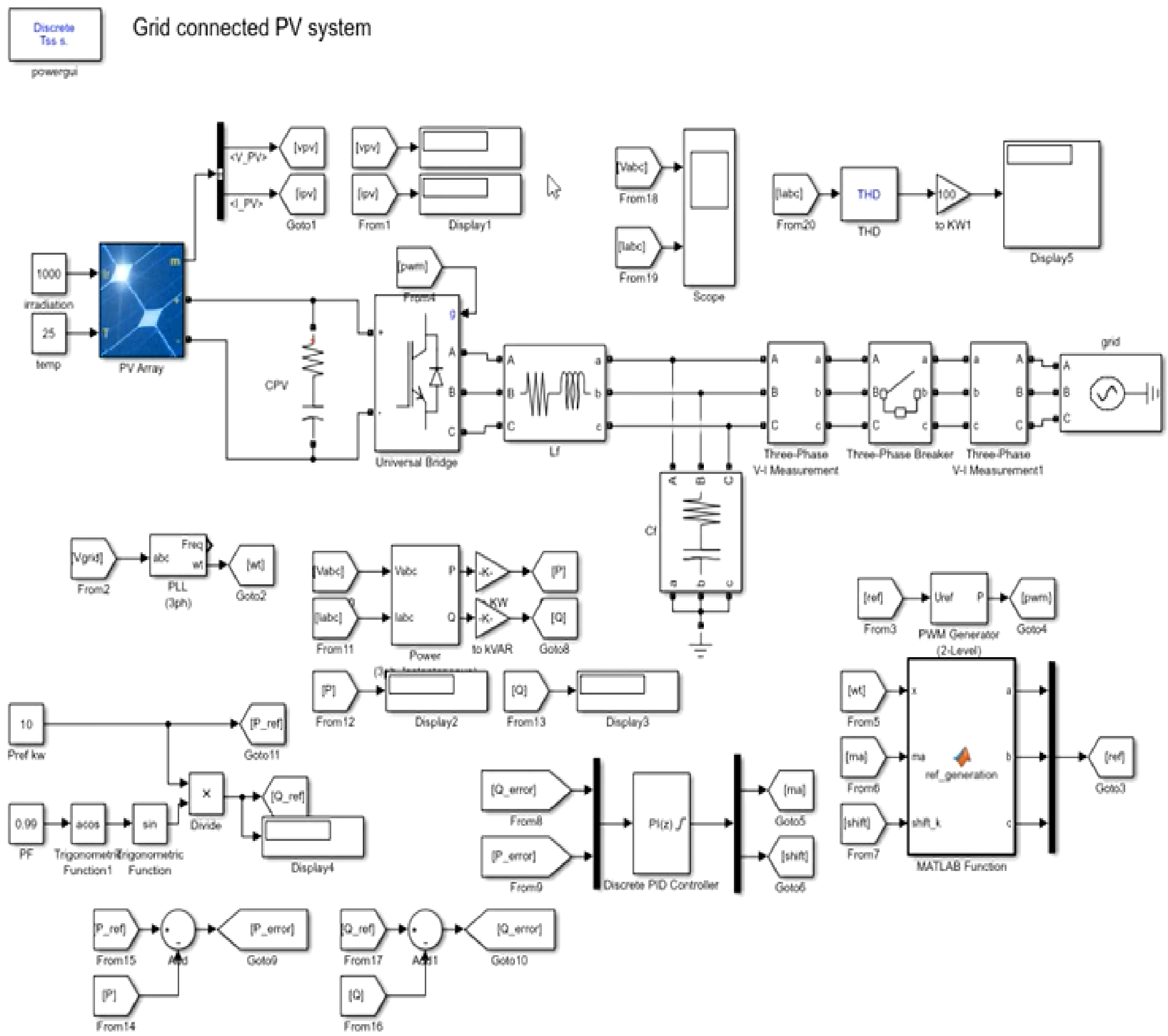
APPENDICES

Simulation System



Simulink/MATLAB code

```
Function y=fcn (u)
Y=u;
Else
If dv<0
Vref=Vrefold-delta Vref;
Else
Vref=Vrefold+delta Vref;
End
End
Else
Vref=Vrefold;
End
If Vref>=Vrefmax// Vref<=Vrefmin
Vref=Vrefold;
End
Vrefold=Vref;
Vold=Vref;
Pold=V;
P=V*I;
dV=V-Vold;
dP=P-Pold ;
if dP=0
if dP<0
if dV<0
Vref=Verfold+deltaVref;
else
Vref=Vrefold-deltat Vref;
end
else
If dV<O;
Vref=Vrefold-delta Vref;
Vref=Vrefold+delta Vref;
end
```

```
end
else
Vref=vrefold;
Function Vref-RefGen(V,I);
Vrefmax=450;
Vrefmin=0;
Vrefinit=400;
Deltav=Vref=5;
Persistent Vold Pold Vrefold;
Data type=double;
If isempty (Vold);
Vold=0
Pold=0
Vrefold=Vrefinit;
end
P=V*I;
dV=V-Vold;
dP=P-Pold;
if dP=0
if dV<0
Vref=Vrefold+deltaVref;
else
Vref=Vref-deltavref;
end
else
If dV<0;
Vref=Vref-deltavref;
else
Vref=Vrefold+deltaVref;
end
end
Vref=Vrefold;
End
```

Goma Electrical Network Data Synthesis

name of the plant	**NURU**	**VIRUNGA (Matebe)**	**SNEL (Ruzizi)**
Load install [MW]	**0.248**	**5.6**	**42.908**
Line length[km]MT	**10**	**63**	**125**
Generation [MW]	**1.3**	**13.2**	**28**
Cosφ	**0.95**	**0.9**	**0.85**
Cable sectio	**70**	**148**	**50**
Transport voltage	**11**	**33**	**15**

Demographic Structure of The City of Goma

populated by indigenous ethnic businesses from the province of North Kivu, such as Nande, Hutu, Nyanga, Kumu, and others. Apart from those indigenous people, the miles have been populated by many tribes from adjacent towns and countries. The table below depicts the population of Goma separated into districts, as well as

Years and Quarters	2002	2003	2004	2005	2006	2007	2008	2009
Goma District								
Les Volcans	7707	8150	9073	9265	10056	10831	8183	10216
Mikeno	30829	32599	36292	37058	37374	37373	37435	40866
Mapendo	32370	34229	38107	38911	39085	41017	42384	42909
Katindo	23122	24449	27219	27794	28272	28488	28659	30649
Himbi	26204	27709	30848	31500	33982	33673	35974	34736
Kyeshero	30829	32599	36292	37058	37311	40665	44914	40866
Lac Vert	3089	3260	3629	3706	4327	4346	4899	4087
Total	**154150**	**162995**	**181460**	**185292**	**190407**	**196393**	**202448**	**204329**
Karisimbi District								
Murara	27403	28978	32260	2941	33866	34086	35032	41796
Kahembe	16442	17386	19356	19764	20185	26978	27616	25077
Majengo	1982	20983	22582	23059	24318	25191	32613	29257
Virunga	8221	7993	9678	1884	11011	11686	19598	12539
Mabanga Nord	38364	40586	45163	46118	46036	46074	38830	58514
Mabanga Sud	63027	66647	74197	113763	78324	78511	81215	96130
Kasika	24663	26080	29034	29647	30908	30196	44196	37616
Katoyi	38364	40568	45163	46118	45940	47200	59375	58514
Ndosho	21922	23181	28081	26353	27681	27819	49841	33437
Mugunga	5481	5795	6452	6588	7965	8214	12179	8659
Bujovu	10961	11591	12904	13176	12936	13759	17472	16718
Total	**256830**	**289788**	**324870**	**329411**	**339170**	**349714**	**417967**	**418257**
General total	**410980**	**452783**	**506330**	**514703**	**529577**	**546107**	**620415**	**622586**

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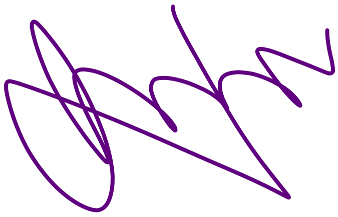

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