Univeristy of Rwanda

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Design of Grid Connected Solar PV Irrigation (DGCSPVI)

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In partial fulfillment of the requirements for the degree of

Masters of Science (Renewable Energy Engineering)

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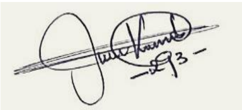
DECLARATION

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 has been in the thesis work will have been fully acknowledged.

Names: **Joel Nzanzu Kanduki** Date:

Signature :



CERTIFICATION

This Thesis Report has been submitted for examination with my approval as the University Advisor.

Thesis Advisor: **Dr. Peter Musau Moses** Date of Submission: 4/11/21

Signature: 

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First of all I am deeply thankful to my Lord for his love, goodness and kindness to me.

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ABSTRACT—

This thesis presents the Design of a Grid-Connected Solar Photovoltaic Irrigation System (GCPVIS) with regard to the Democratic Republic of Congo (DRC). The design includes the, load determination, sizing of the solar panel, inverter rating and the grid integration parameters. Power Quality (PQ) aspects of the GCPVS are also investigated. To conduct this research, the methodology consisted of site selection, which was analyzed and studied. We also defined a suitable area for the System Installation and the choice was made for Beni territory. As we don't have its specific meteorological data due to the inexistence of weather forecast institution, the entire city of Beni was been considered. The system performance for irrigation load to model was calculated through the performance parameters as the specific yield, the capacity factor and the performance ratio.

The simulation was made using the engineering software's MATLAB. The results obtained were analyzed one by one according to output of power, voltage, current of the grid-connected solar PV for irrigation. In calculation, we have found the specific yield and the performance ration at 50KW three phase resistive load at a normal percentage.

As revealed in the literature for filling in as a fast reference to specialists and engineers who are working or intrigued by the subject, the thesis of an MPPT controlled 50KW DC/AC grid connected PV system irrigation is shown. By using 50KW PV group generated with 11 Parallel panels and 21 series. And maximum power is 53KW at 1000W/m2 irradiation. MPP voltage is 850V. The Maximum power is extracted from the PV panel using P&O algorithm at variable solar radiance with a constant temperature of 25^0C. The inverter is used to convert the dc voltage of PV system into ac voltage. The switching frequency of the system is considered to be insufficient as 0.13% compared to 6 pulse and 12 pulses converters. This thesis has the utility which is focalized to analyze all needed steps which will help us to design and build an efficient and cost-effective Grid connected PV system. Note that the integration of the RE into the grid will be facilitated by a PED in other to maintain the reliability and stability of the system and finally achieve the goal for irrigation in DRC specially in Beni Territory.

Keywords: Grid Connected Solar Photo Voltaic Irrigation System (GCPVS), Power Quality (PQ), Democratic Republic of Congo (DRC),

LIST OF SYMBOLS AND ACRONYMS

AC	Alternating Current
AC µGrids	Alternating Current micro grids
CSC	Current Source Converter
DC	Direct Current
DC µGrids	Direct Current Micro Grids
DER	Distributed Energy Resources
DG	Distributed Generation
ESS	Energy Storage Systems
FACTS	Flexible AC Transmission Systems
HV	High Voltage
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IGBT	Insulated Gate Bipolar Transistor
LVAC	Low Voltage Alternating Current
LVDC	Low Voltage Direct Current
MV	Medium Voltage
PE	Power Electronics
PV	Photovoltaic
PMW	Pulse Width Modulation
RESs	Renewable Energy Sources
THD	Total Harmonic Distortion
VSC	Voltage Source Converter
IEEE	Institute of Electrical and Electronics Engineers
kVA	Kilovolts Amperes
kWh	kilowatt-hours
MPPT	Maximum Power Point Tracking
MW	Megawatts
PF	Power factor
PED	Power Electronic Device
DRC	Democratic Republic of Congo

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CHAPTER 1
INRODUCTION

1.1 Background

Diesel-controlled siphons are generally utilized in cultivating and meadow water system. Nonetheless, issues of unwavering quality and accessibility seem the second where fuel supply is inconsistent and costly, high upkeep cost, and short future. With the diesel motors call for accessible elective wellspring of force for irrigational water pumping, these and ongoing worries for the climate are related. In DRC, electricity represents only 2% of the energy consumed [1]. It was found according to data collection that the total power demand of Beni area is less than the irrigation load. To solve this issue, the use of a Grid-Connected Solar Photovoltaic Energy for generating electricity for irrigation load is mostly solicited and designed in this thesis. Since there was no census done in the 4 past years, some estimated values were used in the simulation. In Democratic Republic of Congo/ DRC, most rural areas don't have that opportunity to be connected to the grid electricity to drive the water pumps for irrigation. The integration of RESs frames new nearby energy frameworks, for example, microgrids (MGs). In the manner to accomplish the best financial advantages and natural outflow decrements, the ideal arranging of MGs has gotten a lot of consideration. Results showed that the Grid-Connected Solar PV for water system, is more conservative. Moreover, in the proposed thesis the practicality of battery stockpiling framework (BSS) was not explored. The Optimization results delineated that the best arrangement for the lattice associated working for water system load is the mix of a crossover framework Solar PV and Grid. As we know the PV cell is the primitive working component and converts over straightforwardly the sun-oriented energy coming from daylight into electrical energy which is in DC form, and then this energy will be convert in AC form by the power electronic device (Inverter) to improve the conversion efficiency in other to be synchronize with the AC Grid. There are control functions in grid-connected PV system we should respect: $Vgrid = V\sin(2\pi ft + \theta)$; Grid synchronization is the process of obtaining information about the grid voltage; which means that we should have the same frequency, the same phase and the amplitude of the voltage. This data is utilized to synchronize the exchanging of the inverter from the RE source into the grid voltage, which ensures that we have at the same frequency, the same phase output as well for both the PV and the grid.

1.2. Problem Statement and Justification

The power quality and reliability problem in term of voltage, current of the output on PV grid connected is analyzed by conducted method of experiment with load (motor pump). Most of Congolese don't continuously harvest each year because of low irrigation farms which is could be supported by technology if it was widely applied. The city of Béni, located in the DRC is facing a major problem of electricity supply for irrigation. This situation is linked to the insufficient electrical power produced by the hydropower station managed by SNEL[1]. Agriculture being the mode and lifestyle of the population of Beni, the interest of interconnecting the grid with solar energy gives value to our subject. Using the grid connected PV powered pump is the best solution to increase profitability of the farmers.

1.3. Objectives

1.3.1 Principal Objective

The principal objective is to design and evaluate an efficient and cost-effective Grid-connected Solar PV power-driven water pump system to be used for irrigation.

1.3.2 The Specific Objective

i) Collect operational data of currently operating water pumps with solar PV in DRC and make evaluation of their performance due to utility.
ii) Design and evaluate an efficient and cost-effective Grid-connected Solar PV water pump.
iii) Simulation of the system using MATLAB software

1.4 Research Questions

i) After collecting data of the currently operating water pumps with solar PV in DRC, how can the hybrid Grid-Connected Solar PV can affect positively the farmer's life compares to the conventional one?
ii) Is the Designing of a Grid-Connected Solar PV system can increase the access rate of population to irrigate field in Beni area?
iii) Economically, is this software can assure positively the real existing structure for the rural life population?

[1] SNEL « Société Nationale d'Electricité » is a public company which manages electricity in the DRC.

1.5. Scope of the Study

This thesis has been partitioned into few parts. It deals with design and evaluation of a Hybrid Grid-Connected Solar PV system for Irrigation. The literature review on the PV System for irrigation, topology and its operation also gid-connected PV System has been found through to have a better comprehension on the system. The simulation of the system is done with MATLAB software and validated using DRC data to analyze the result by experimental. Note that in this thesis the irrigation load is not analyzed at depth.

1.6 Report Organization

This thesis is organized as follows: The Chapter One contains the introduction of the subject with the Background, problem statement, objectives and research questions. The second Chapter talk about both literature review of the problem formulation. In the Chapter Three the focus of the work is to develop good methodology by referring to the previous one used by other researchers. The Chapter Four is analysis of result running with MATLAB software while the Chapter Five is the Conclusion and Recommendations for further work. Finally, there is a list of References used and Appendices.

CHAPTER 2
LITERATURE REVIEW

2.1. Review of the Grid-Connected Solar for Irrigation Problem

Kazem HA, et al (2015) [2] [1] introduced how the ideal plan of a PV system used to work a water pumping not really set in stone for Oman. Zeroed in on the natural states of Sohar city, the system configuration was influenced profoundly and thus. To demonstrate the adequacy of the proposed framework, the execution and estimation of the planned framework are introduced. The outcomes show that after experimentation at top hours, the framework can give the necessary force, respecting an impressive decrease in the estimating of the PV system. Along these lines, in result, the speculation capital expenses 2400 USD and the expense of energy is equivalent to 0.309 USD/kWh. Furthermore, the impacts show that the grid yearly yield factor is 2024.66 kWh/kWp and that the limit factor is 23.05 %, which is empowering since the last is regularly 21 %. The grid capital expense of venture and the expense of energy merit contrasting with a diesel generator. Between the normal framework and different others in the writing there is a correlation made. Also, the correlation demonstrated that the grid cost of energy is great.

Hamidat A, et al (2003) [2] demonstrated that in Algerian Sahara areas for low heads it is feasible to utilize a photovoltaic water siphoning framework for limited scope water system of harvests. Hence, the photovoltaic water siphoning framework could without much of a stretch cover the day-by-day water needs rates for limited scope water system with a space more modest than 2 ha. Likewise, the PVPS could upgrade the way of life (day to day environments) of the rancher with the assistance of the extension of the neighborhood cultivating. What's more, subsequently, the departure from provincial regions (rustic termination) will be finished.

Mansur A et al [3] gives the outcome of the most recent or the momentum distributed writing on sun based fueled water siphoning frameworks. The paper contains research propels, uses of such frameworks and dimensioning parts (estimating). Likewise, the paper talk over the commitment of the utilization of sun based fueled water siphoning framework in lessening the discharge of carbon dioxide to the climate. It has been seen that essentially all the introduced sun based fueled water siphoning frameworks siphon heads don't surpass 200 m. This sort of siphons are introduced in excess of 18 nations all throughout the planet and 33% of these nations are in Africa. The synopsis writing on sun based controlled water siphoning framework nitty gritty that such frameworks contrasted with diesel and wind-fueled water siphoning frameworks are more efficient and cheaper at low siphoning limits and that sun based controlled water siphoning frameworks will partake with other driving frameworks if their comprehensive expense is under 5$/Wp. The utilization of sunlight based controlled water siphoning frameworks by lessening the fossil fuel byproduct (no utilization of petroleum derivative) contributes, award, supply to a perfect climate and by speeding up carbon sink because of an increment in meadow. This audit paper filling in as a speedy, a splendid reference to engineers, specialists, understudies and other people who have interest on the specialized and monetary practicability, convenience and value of sun oriented controlled water pumping system.

Ali H.A. et al [4] deliberately, planned, assessed, assessed and surveyed a PV water siphoning framework for Sohar-Oman. The exploration characterized the system parts with ideal qualities as PV modules, inverter, charger regulator, batteries. The system has an everyday heap of 2.22 kWh/day, 0.84 kW PV modules, 0.8 kW inverter 4, and batteries, (12 V and 200 Ah). The impacts showed that the ideal PV system energy cost was 0.309 USD/kWh. Contrasted with the diesel motor energy cost that was 0.79 USD/kWh, the result makes the system an alluring choice. By and large, the PV system choices were achievable contrasted with the diesel generator choice. The PV sun-based water pumping system is commendable, admirable and extraordinary choice for water system in provincial spaces of Oman. The review tells out, spread the word about that removing the diesel generator by PV system protect and save the climate from the ozone harming substance outflow. The executed, the applied system tests showed that in the pinnacle hours the PV cluster delivered sufficient force that made no requirement for batteries and tank.

As indicated by Lawrance W, et al [5] the results from the undertaking to date are empowering and influence a decent connection between's the model and the test results from the system. A signiscant improvement over existing system, over a scope of working conditions is shown by its system productivity esteems. It is more significant at this stage to focus on vinifying the dependability of the system while enhancements in productivity are as yet conceivable. This system worked with being set up a PC based information securing framework which will empower long haul tests on the framework to run automatically.

T. Vijay Muni and Lalitha [5] presented a new perspective to upgrade, rise and improve the photovoltaic water pumping (PVWP) system for irrigation has been proposed with the consideration of groundwater response and economic factors in this paper. This implied a reduction of 18.8% in the speculation capital expense and thus update the financial chance of PVWP unmistakably. Regardless of whether the duty of PV modules and yields are the key boundaries in regards to the monetary feasibility, adjusting to the discernment study, they don't have unmistakably effect on the satisfactory, best and consistent state framework limit if the spring water level is restricted. Albeit, the spring water level reaction to providing doesn't address a limitation, the extension of the rummage value endeavors to raise the PVWP limit; while the augmentation of PV value endeavors to diminish it.

Yu, Ying dong, et al [6] presented the Solar PV powered irrigation as a successful system that can bring on to grasslands or habitat conservation. This review takes a gander at precipitation, tendency, and water quality as managing factors. The fields (in the review region) that meet the above capabilities and determinations cover around 8.145 million hm or 22.3% of the complete lush space of Qinghai Province, our picked subject. A space of around 995,000 hm is reasonable for surface water system, representing 12% of the all-out region regarded sensible for water system;

Dr. A, et al [7] focused on completing the most energy effective control calculations for AC machine-siphon loads in which MPPT following and greatest engine and pumping execution (effectiveness) are the system implementations targets. Regularly, the system esteem and the discount of the amassed piece of the recorded expense of a decent resource that has been charged to discount over the system life are fundamental fixings. The paper has focused on pumping system since water for horticultural use is a widespread use in distant spots (regions) having top insolation levels and the need or the commitment of independent power. The innovations oblige in the survey are normally proper or identified with cooling and refrigeration applications also those difficult coordinated half breed power sources. By and by, the plan of PV-drive system and control feel the need of various regular issues to be reacted.

Qing Liu, et al [8] presented the usefulness or the utility of solar photovoltaic water pumping system. It has been checked on for three chose locales in Ethiopia. The portray framework have the capacity of giving a day by day normal of 10.5, 7 and 6.5 m3/day for 700, 467 and 433 agrarian woodlands in Siadberand Wayu, Wolmera and Enderta destinations, autonomously, with standard day by day water assets the executives or water usage of 15 liters each day for every individual. Also, the expense of water, except if any portion or award, are near or practically 0.10, 0.14 and 0.16 $/m3 for Sideband Wayu, Wolmera and Enderta destinations, autonomously. In the event that a 20% award is considered all through reenactment, the expense of water would cut down or diminishing to 0.09, 0.13 and 0.15 $/m3 autonomously;

S. Ould-Amrouche, et al [9] discusses the way of supporting the spreading (dispersion) of the PV siphoning innovation, an as of late created engine siphon subsystem model is created to concede or to approve the estimate of PV siphoning establishment water yield flow. The average (model) conveys the water flow yield (Q) straight as a reason for the electrical force input (P) of the engine siphon subsystem. By contrast the recreation results and the estimation information, the model is affirmed and supported.

2.2. Research Gap

In this area of research as well as this sector is concern; after reading those papers and documents we have found that the grid-connected solar PV is on increase; the irrigation situation is a crucial load in DRC, then it was been suggested to improve design the reliable and efficient system for DRC. Efficient power was produced when it was needed without transformer losses. This thesis endeavor to plenty such a research gap by promoting or come about a novel method for the suitable, moderate (optimal) design of the Grid-Connected solar PV for Irrigation based on the long-term load demand forecasting.

2.3. Problem Formulation

2.3.1. Simulation Model

The majority of DC renewable sources and the permanence of PEDs, currently had been attracting enormous interest as a mean to in hence the use of electrical energy efficiency and it operate bidirectional power sources at their point of connection with the conventional system. As shown in Figure.2.1 the PEDevice (converter) is a key element.

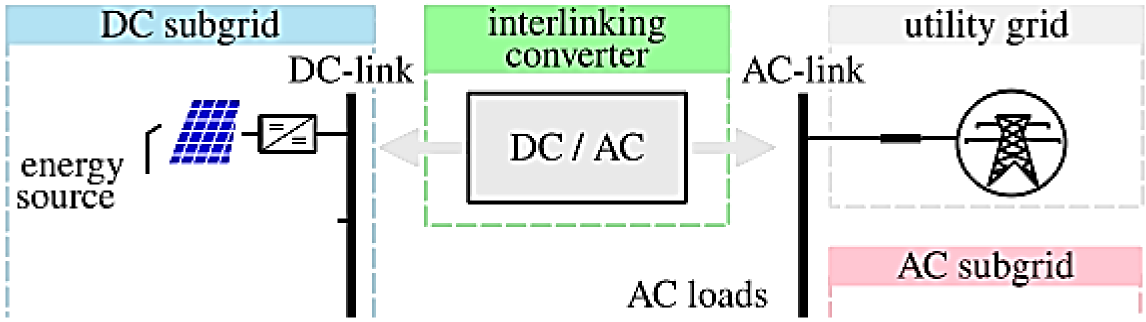

Figure 2.1 Assembly of a Hybrid DC/AC Microgrid.

2.3.2. PV Efficiency and Mathematical Model

Many materials which absorb light and turn it into electricity can make the PV effect. Solar cells are manufactured for strong PV effect. However, efficiency is taken into consideration. If a solar cell efficiency is 15%, the electric output power of a 1 m^2 cell which receives 1000 W/m^2 irradiance at a temperature of 25°C; would be 150 W. The fundamental building block of Solar PV array is shown in Figure 2.2. It consists of a photodiode that generates DC current from the solar irradiance through the photovoltaic effect [10].

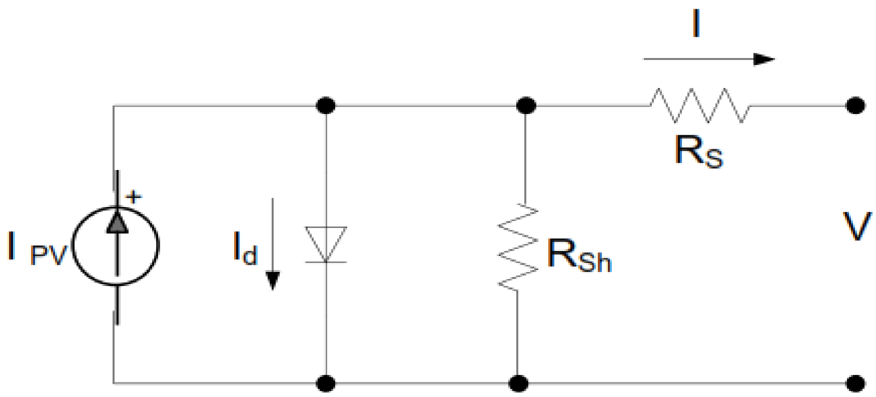

Figure 2.2 One Diode Equivalent Circuit of Solar PV

$$I = I_{PV} - I_O \left[exp\left(\frac{V+R_S I}{V_{therm} a}\right) - 1\right] - \frac{V+R_S I}{R_{sh}} \tag{2.1}$$

For I_{PV} and I_O are respectively the current that is generated in a photosensor as a result of incident radiation (photo current) and the reverse current in a semiconductor diode caused by spreading of minority carriers from the neutral regions to the exhaustion region (diode saturation current), with

$$V_{therm} = N_S kT/q \tag{2.2}$$

Where the thermal voltage of the PV array is V_{therm}, N_S the number of cells joined end to end (connected in series) for greater output voltage, k is the Boltzmann constant ($1.3806503 * 10^{-23}$ J/K), T (Kelvin) is the temperature value, and q ($1.60217646 * 10^{-19}$ J/K) is the electron charge. Also, R_S and R_{sh} are the equivalent series and shunt resistances of the array, respectively, and a is the understanding factor which is habitually chosen between 1 included up to 1.5 included.

The practical PV array is constituted by several solar cells. In Figure 2.3, the I-V characteristics of a solar array is shown.

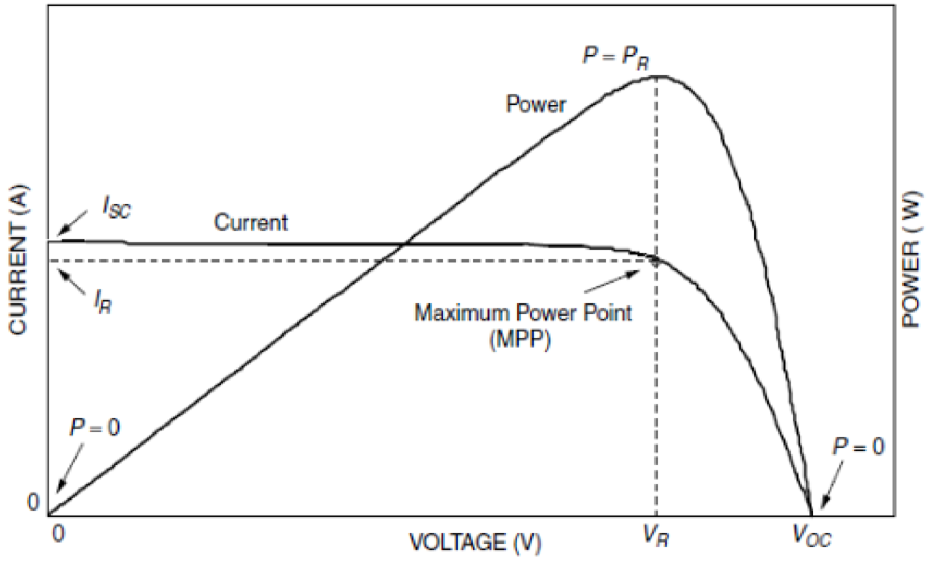

Figure 2.3 Solar PV Characteristics

2.3.3. Inductor Current Controller

When sampling time is zero, L dynamic equation, the derived duty-cycle control equation is

$$d(Q) \quad = \frac{Lf_{sw}}{V_{DC}}.[i_L^{REF}(Q) - i_L(Q)] + \frac{V_0(Q)}{2V_{DC}} + \frac{1}{2} \qquad (2.3)$$

between the current reference i_L^{REF} and the inductor current i_L, The resulting discontinuous-time, feedback control function W_{iL}, is equal to a unit delay:

$$W_{iL}(Q) = \frac{i_L(Q)}{i_L^{REF}(Q)} = Q^{-1} \qquad (2.4)$$

the expressed sampling period $\left[i.e., \frac{T_{SW}}{2} = \frac{1}{2f_{SW}}\right]$.

2.3.4. Output Voltage Controller

The real equation is like an assuming derived of the reference current described (2.1). considering the zero-order hold, the output voltage equation is composed for two following modelling frequency of time scale $\frac{T_{SW}}{2}$

$$V_0(s+1) = V_0(s-1) + \frac{1}{2C_0 f_{SW}}[i_L(s) + i_L(s-1)] + -\frac{1}{2C_0 f_{SW}}.[i_L(s) + i_L(s-1)] \quad (2.5)$$

As shown in (2.2), the average of the current conductor with reference current, the output current is not to very important. The output voltage equation is written for two consecutive sampling periods described in (2.3):

$$V_0(m+1) = V_0(m) + [i_L^{REF}(m) - i_0(m)], \quad (2.6)$$

where m as an index is considering once time per period. As shown in the formular. represents the previous formular show the down-sampled energetic equation of the output voltage for the the inverter, then the we can derive the control equation:

$$i_L^{REF}(m) = C_0 f_{SW}.\,[v_0^{REF}(m) - v_0(m)] + i_0(m) \quad (2.7)$$

Let us assumed $V_0(m+1) = v_0^{REF}(m)$ The previous formular applied to (2.4) prove that, the reference current, i_L^{REF} is unvarying in two consecutive sampling frequency of duration $\frac{T_{SW}}{2}$:

$$i_L(Q) + i_L(Q-1) = i_L^{REF}(Q-2), \quad (2.8)$$

Used as a (2.5) derivate. by integrating the output capacitor, we obtained the current while the average inductor current is stationary.

$$V_0(m+2) = V_0(m) + \frac{1}{2}[v_0^{REF}(m) + v_0^{REF}(m-1)] - \frac{1}{2C_0 f_{SW}}[v_0(m) + v_0(m-1)]$$

$$\frac{1}{2C_0 f_{SW}}[i_0(m-1) + i_0(m+1)] \quad (2.9)$$

By the previous formular (2.7), resolving the equation, the signal transfer change and become equal to: $W_{vo}(Q) = \frac{v_0(Q)}{v_0^{REF}(Q)} = \frac{1}{2Q-2Q+1}$ (2.10)

It is not affected or necessary change, with the solution from (2.7), $the\ delay\ of\ W_{vo}$ is not worth.

2.3.5. Grid Current Control

When the parameters will be injected into the grid, it will react with a certain short delay response, because of the controller of the interlined grid current i_G, unexpectedly with a simple PI regulator of the kind:

$$H_{PI}(Q) = K_p + S_i \frac{Q}{Q-1} \quad (2.11)$$

2.3.6. Grid Connected Operation

The grid impedance for the system is given by

$$Z_{O,iG}(Z) = \frac{v_O(Z)}{i_G(Z)} = \frac{C_0 f_{SW}.H_{PI}(Z)+Z-1}{C_0 f_{SW}.(2Z^2-2Z+1)} \quad (2.12)$$

According to our project, I will apply the smart PE device which will be connected between both electrical power generation (grid) and RE generation with the goal to maintain the reliability and the efficacity of the power quality and achieve the need of doing irrigation.

2.4. Chapter Conclusion

Generally, the stability and the reliability of the power -converter-dominated requires to respect and to maintain issues such us good ability of power to maintain steady acceptable voltages (voltage stability), power angle stability, and frequency stability. The significance of this chapter is to understand from other researchers the challengers which can appear and solutions which can support the security of the system GCPV in other to achieve the goal.

CHAPTER 3
METHODOLOGY

3.1. Previous Method

The previous method was focalized to improve the power reliability with the national grid by using diesel resource as background. Unfornatly that one is not friendly environment. They used just to check the grid voltage and the frequency protection They had disturbances into the system and the power quality was affected.

3.1.1. Phase Shift Method [11]

We call it slip mode frequency shift method (SMS), this method constraint the phase of the inverter's output to be smoothly in other to be integrated but unfornatly cause fluctuation in the inverter current which is recognized by a PLL and affect by increasing efficacily the normal operating frequency;

3.1.2. Reactive Current Injection/Absorption Method [12]

This method has the role to inject the reactive power toward the principal grid in other to support voltage recovery and comfort the stability of the power system. Unfornatly this method cannot work without the support of the performance synchronously with LVRT/ZVRT during the under-voltage period in order to speed up the voltage after a fault and preserve the voltage stability.

3.1.3. Time-domain Simulation Method [13]

This method works on the cooling-off period of the system state and have the good quantity of counting up and prime time expenditure but unfornatly the typical model and explanation of the method requires to provide the speed of simulation and reduce the instability in the system.

3.1.4. Lyapunov Method [14]

This method is focused on the estimate of the attraction and the speed of stability of the system, we call it the transient energy function method because it shares out with the power angle stability out of the energy belief, but the problem is still at the position where it is always difficult to puzzle out the energy function and make a good analysis process.

3.1.5. Hybrid Method [15]

This method incorporates both the time-domain simulation and lyapunov method. Firstly, by managing time-domain simulation we obtained the structure variable curve, secondly according to the trajectory the energy of the system is finding. Let us note that the power angle stability of the system is already estimated. The hybrid method should maintain the stability analysis of power system. unfornatly, this method needs more investigation because of its weakness for the power-converter-grid.

3.2. Proposed Method

3.2.1. Perturb and Observe MPPT Algorithm P&O [16]

The utility of this method is to assess the power quality and reliability and how it could be enhanced in the irrigation domain using the DC/AC converter MPPT for Grid connected PV powered pump as the best solution to increase profitability of the farmers. By identifying existing system distribution and their deficit, we will start by there. Different authors talked about this area of research then we will consider some previous works as important input to conduct the study. Design and analysis will be done by some calculations of different components' sizes, the cost recovery of the system and after the result will be analyzed and simulated employing software (MATLAB/Simulink) expressly to see the system performance.

3.2.2. Frequency Shift Method [17]

Is called active frequency drift (AFD) method, note that this method is simple to be carry out in PV inverter using a microprocessor in other to control essential zero cost when the current is injected.

3.2.3. Current Magnitude Variation Method [18]

We call it Scandia Voltage Shift (SVS) method, it usually used the positive feedback in the system in other to prevent islanding by maintaining the amplitude of the voltage. It used to maintain the output power during variation period and it has the capacity of the excellent-power quality without injecting harmonic signal during connected.

3.2.4. Frequency Stability Regulations and Active Power Control Method [19]

In the electrical grid, a steady frequency must be kept up (typically 50 or 60 Hz), at any given time the equality between the interested power output to the load demand should be respected in other to reduce variation between electricity supply and demand which bring about the frequency to deviate from its model value. The management control serves as primary load control and put a stop to a large frequency deviation.

3.2.5. Voltage Stability Regulation and Reactive Power Control Method [20]

We can find the problem of disturbance of the reactive power balance of the grid at the coupling or junction point between both the main grid and the renewable source which can cause the fluctuation of voltage; this method used by an inverter control help to balance and control the reactive power and maintain the good stability.

3.3 Solar PV Integration

3.3.1 Overview of the Solar PV Integration

Solar PV Integration comprises of an organization that permits the infiltration of PV age into the utility network. This training is applied now in numerous nations as they need clean energy. In the interconnection cycle, an inverter, which is the main hardware and furthermore the cerebrum for the coordination framework, assumes the part of force gadgets interface between the exhibit and utility organization. It guarantees many capacities for the framework to work accurately. Other system parts of a sun powered lattice reconciliation are PV modules, transformers, meters, DC and AC wiring, and so on [21].

The PV inverters are required to supply constant voltage and frequency instead of the changing load conditions. It additionally needs to supply or ingest receptive force on account of responsive burdens. Inverters are additionally assuming the part of the human-machine interface (HMI) for some PV system, and frequently perform information assortment obligations to follow and impart the system execution to the proprietors and administrators [22].

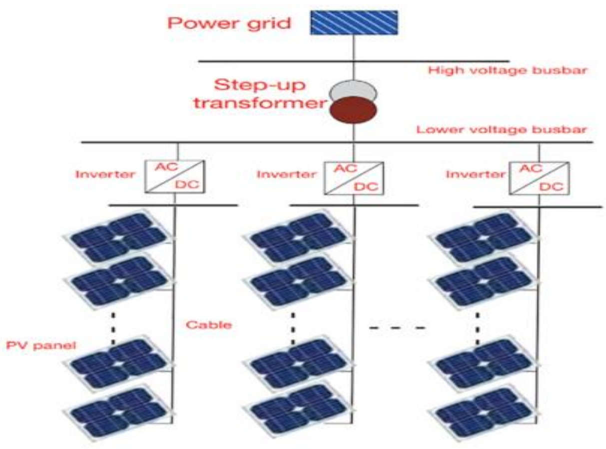

Figure 3-1: Grid-Connected PV Power System [22]

3.3.2. PV Penetration Level

The penetration level for a PV power plant has been defined differently in past researches. It is defined as the ratio between the maximum PV power and the maximum apparent power of the load. It is expressed by Equation (3.1) [23]:

$$PV\ Penetration\ Level = \frac{PV\ generated\ capacity(kWh\ or\ MWh)}{Network\ Peak\ Load(kWh\ or\ MWh)} \quad (3.1)$$

Past works gave percentages values for a high penetration level for PV. Authors suggest values that are greater than 20% of total generation, while high penetration is considered from others at the levels going up to 15% and 50%, respectively. Although no standard says what percentage constitutes a high PV penetration, many types of research precise that at penetration above 15%, the challenges of high PV penetrations become noticeable.

3.4. Challenges of the Large-scale Solar Integration

The impacts of the integration of solar energy into the grid need high attention from utility companies and researchers. These impacts cannot be generalized for all the types of grids around the world. Studies are needed to be carried out before the integration process [28]. Some of the challenges are discussed in the following paragraphs:

3.4.1. Reverse Power Flow

In many power systems, the flow of power is done in one direction. This comes from centralized generators up to substations and then to consumers. This is not the same for solar PV power systems. Here, the flow of power can be done in both directions. Since that many electric distributions were not designed for such operation, even small amounts of PV may affect system parameters. When the generation coming from PV exceeds local energy demand, energy will move through the distribution feeder and possibly through the local substation, increasing the potential for damage to the utility grid. Other customers served by the same distribution circuit are also impacted. [21]

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3.4.2. Power Quality Issues

Some challenges include problems of voltage stability, frequency stability, and overall power quality. When the load of the system is greater than 10 MW, the distributed system is considered large-scale. Many issues related to power quality occur with a system under 10 MW. However, large-scale systems also face power quality challenges. The production and demand of electrical energy can be matched for a conventional power system. Photovoltaic energy does not have the luxury of producing power according to the demand. Power quality is assimilated to water quality; just as water suppliers must meet certain conditions for bacteria and pollutant levels, utility power is consistently supplied at a certain voltage and frequency.

In the DRC, residences, commercials, buildings and industries receive single-phase AC power at 220/380 V and 50 Hz or higher voltage three-phase power, depending on the size and the types of loads. Appliances and electronic devices are manufactured to be supplied by a certain range of voltage and frequency. Damages occur with deviations outside those ranges. This shows the importance of Power quality. [28] [24]

a) Harmonics

The harmonics problem is one of the power quality issues, it is generated mainly from power inverters. They are created by some loads which introduce frequencies that are multiples of the fundamental frequency and can cause equipment to not operate as intended. The sum of all the distortions, at the various harmonic frequencies, is called Total harmonic distortion (THD).

Non-linear loads can be the cause of generating harmonics. Modern interconnection requires to include limits on harmonic injection from DG, and devices evaluated to meet IEEE 1547.1 standards will have a minimal harmonic impact.

b) Power Factor

The Power factor (PF) is a measure of apparent power that is delivered when voltage and current waveforms are out of synch. It is also defined as the ratio of true electric power, in watts, to the apparent power, in volt-amperes (VA). Loads with motors typically cause reduced (or lagging) power factor. The terms leading and lagging are describing whether the current wave is ahead of or behind the voltage wave.

c) DC Injection

When the inverter transfers undesirable DC current into the AC (or output) side, DC injection occurs. This can be prevented when galvanic isolation is incorporated through a transformer within the inverter design.

d) Voltage Fluctuations

Voltage quality issues that must be also considered as a challenge. Voltage oscillations are caused by changes in the power drawn by a load or output from a DG system. Disturbances classified as short-duration voltage variations are voltage sag, voltage swell, and short interruption, whereas disturbances classified as long-duration voltage variations, include sustained interruption, undervoltage, and overvoltage. The synchronization requirement in IEEE 1547-2003 allows for a 5% voltage fluctuation. The PV plant should be adaptable to voltage sags just as conventional power plants. The operating condition under equilibrium must be restored by the grid between the load demand and supply. If this does not happen and the voltages at some buses or points in the power system rise or falls beyond the limit, then instability occurs. [21] [25]

e) Variability of Insolation

The quantity of generating for the PV depends on the insolation level at a given site and time. The grid instability is coming from both over-generation and under-generation.

3.4.3. Islanding

Islanding describes a portion of the grid that is unintentionally energized. When the grid loses power for intentional (scheduled maintenance) or unintentional (blackout caused by network trip or damaged lines) reasons, interconnected DG solar PV systems will produce power and may feed into the grid. This scenario poses safety concerns for utility line workers, first-responders, and others that interact with power lines during grid failure, who need to know when lines are energized. Islanding from DG solar PV is unusual, as inverters are designed to disconnect from the grid during power failure events. [26]

3.4.4. Cost of Implementation

When a customer (residential, commercial, or industrial) wants to build DG solar PV and connect to the electricity grid, this process is called interconnection. Customers must get approval from their utility before they can build a solar PV system and interconnect to the grid. The purpose of the interconnection process is to maintain safety and reliability, as well as makes sure that any additional costs such as technology upgrades are accurately allocated. The size and location of the solar PV installation, characteristics of the load, and proximity to other DG solar PV installations and substations all impact the results of the interconnection screen. The interconnection process often includes a series of "technical screens" to address concerns about safety, reliability, and impacts on the grid. Additional screens or studies may be needed if a proposed system does not pass the initial technical screen; often at the cost to the developer or property owner who is applying for interconnection. These additional screens may include an interconnection feasibility study, an impact study, and a facilities study. Similarly, delayed interconnection processes add to the total time it takes from conception to completion of the project, which increases the soft costs of solar. Some customers may be allowed to interconnect only if they install costly technology or pay for improvements. Potential customers may also be deterred from installing solar if they know that interacting with their utility through the interconnection process may be lengthy, difficult, or ultimately add to the cost of solar. For large-scale PV projects or farms, most of which are located in remote areas, they often require long transmission lines. This also requires more investment. [23] [26]

3.5. Solutions to Solar PV Integration Challenges

To overcome these above issues, storage solutions along with other instantaneous power-producing solutions are under research and development. Some possible solutions that could mitigate problems:

i) Reactive power/voltage control by use of either series or shunt flexible alternating current transmission systems (FACTS) devices in distribution grids (SVC or DSTATCOM). Also, the use of the minimum import relays (MIR) and the Reverse Power Flow Relay (RPFR) is encouraged for grid-tie systems.

ii) Use of advanced inverter control of voltage, active and reactive power could solve the impacts under different operating conditions for the PV plant.

iii) Distribution grid reorganization/rearrangement. That is the conversion of a radial grid to a meshed or loop distribution grid to increase the hosting capacity and to control voltage levels. [27]

Others challenge mitigation solutions for integrating solar PV are listed as follow:

- A study must be done to predict the behavior of the system when integrating solar PV
- Install solar across a large geographic area to reduce the variability of generation due to shading effects or local cloud cover.
- Store the excess electricity for a later use
- To make sense to customers by using electrical power when it is necessary. This can shift the demand.

3.6. Renewable Energy Integration Interfaces

Distributed generation systems are generally classified according to the type of generator that plays the role of the system interface to the grid. These can be [28]:

- Solid-state or Static Inverters,
- Induction Machines
- Synchronous Machines.

These can be summarized in the following Table 3.1.

Table 3.1: DG System Types and Characteristics

	Inverter	Induction Machine	Synchronous Machine
General Characteristics	Commonly current source-like (strictly, voltage regulated, current-controlled) in grid-tie mode; voltage source in stand-alone mode, sometimes within the same unit. Low inertia (capable of high-speed response).	Inherently current source; can be made to act as a voltage source with external excitation. High inertia (relatively slow response)	Voltage source. High inertia
Fault-current capabilities	Low (typically <1.2 times the normal current).	Medium (6 times the normal current).	High (10 times the normal current).
Power quality	Total Harmonic Distortion and DC injection must be controlled, controllable power factor.	Low Total Harmonic Distortion, power factor must be corrected.	Low Total Harmonic Distortion, controllable power factor.
Examples	Fuel cells, PV, microturbines, some wind turbines.	Some wind turbines, CHP.	Solar thermal electric, diesel generators, traditional utility generators.

The chance is there to fuse security and functional elements into their controls, such to give safeguard plans that keep the inverter from working except if its defensive capacities are working appropriately. The interconnection gadgets could be tried to guarantee that they could dependably give standard utility defensive capacities (voltage and frequency trip), just as extra security components, for example, hostile to islanding.

3.7. Overview of Grid-Connected Solar PV Irrigation

This diagram at Figure 3.2 explains the general scheme of the system and show how making the integration of source for pumping water. After making the integration between both renewable source and grid then we connect to the load. It shown us the entire explanation from the both dc and grid sources into the inverter up to the application (load) of irrigation side. The overview of the Grid-Connected Solar PV irrigation shows us the real way how the system works.

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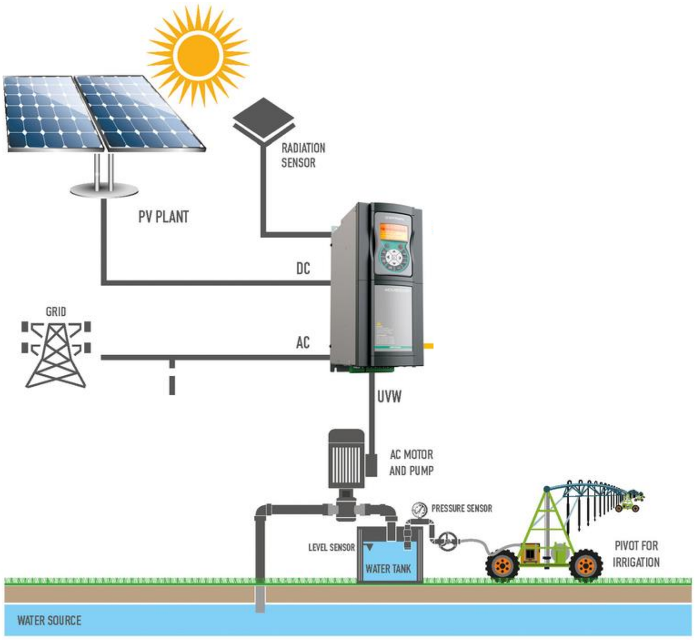

Figure 3.2. Grid-Connected Solar PV Irrigation *[29]*

3.8. Proposed Algorithm for the Grid Connected PV System *[30]*

The figure 3.3 explains the flowchart of all the system, since the start of collecting data up to the supply to load by respecting all characteristics needed for the hybrid system.

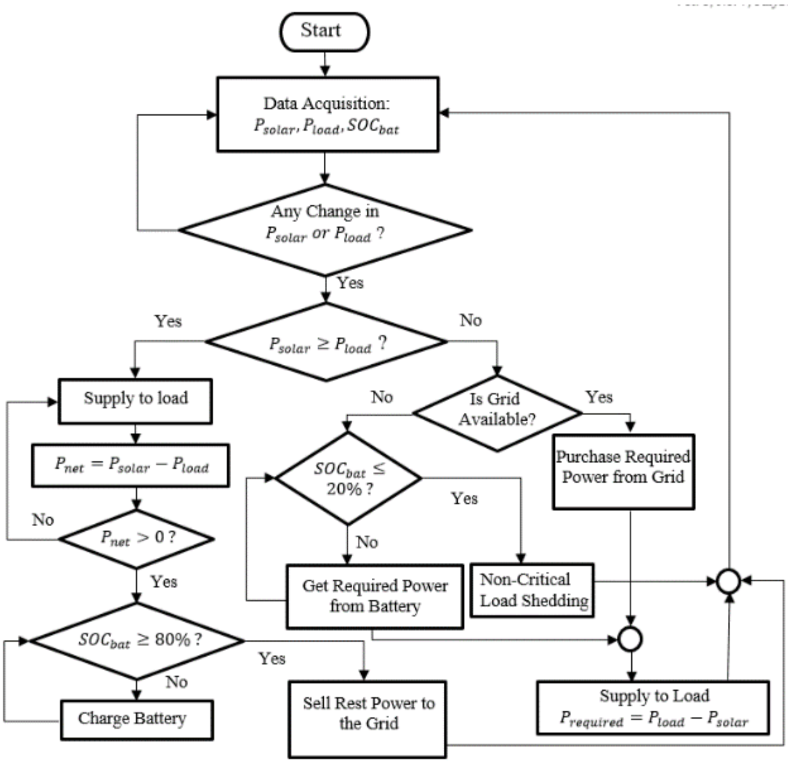

Figure 3.3 Proposed Algorithm for the Grid- Connected PV System

3.9. Case Study

The case study of the research is focalized to analyze the possibility to maintain reliability and a good power quality using a Grid connected PV System as the best solution to increase profitability of the farmers for irrigation in the DRC specially in Beni Territory.

3.10. Mapping Method to the Problem

This method will be helpful because it will increase the power quality and reliability using new and modern power electronics devices such as DC/AC converter by interfering with both RE and Conventional grid. After identifying needed, determine sizes of components and make a good implementing, then the integration of the RE will be succeful and will solve sustainability and reliability problems.

3.11. Conceptual Framework

Here below in the Figure 3.4 it is shown the sketch which shows the conceptual framework of research methodology that will be used:

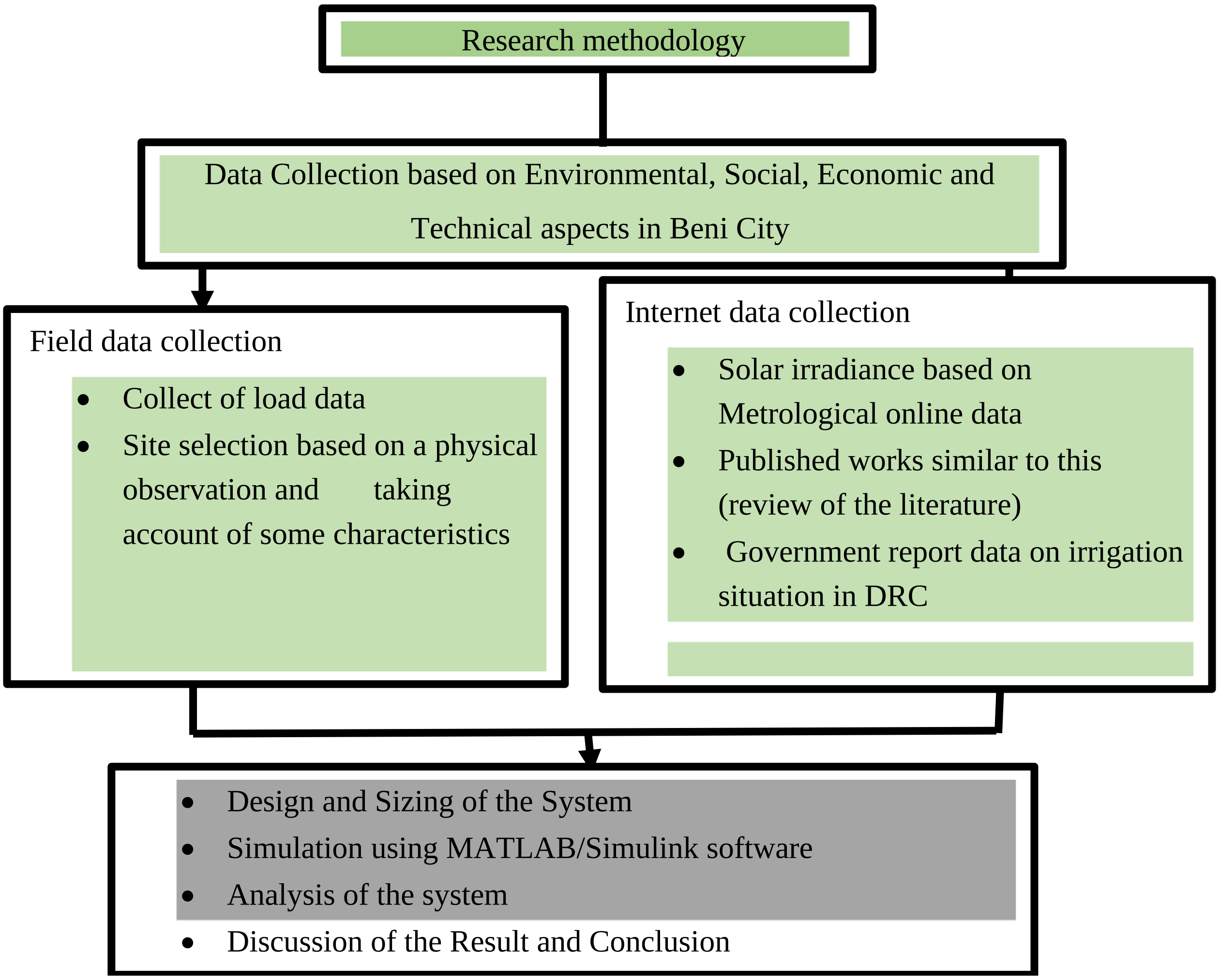

Figure 3.4: Conceptual Framework

3.12. Chapter Conclusion

The significance of this chapter focused on the efficacity of the methodology used to achieve the work. Regarding to previous methods, the Proposed Conceptual Framework will be used in our research as proposed methods to evaluate, make analysis of the system and to appreciate the different techniques with their influences and impacts on the power quality and reliability problem.

CHAPTER 4
RESULT AND ANALYSIS

4.1 Site Selection and Metrological Data

4.1.1 Selected site

The city of Beni is located at 29.2 ° longitude East and 1.7 ° latitude South. The annual solar irradiation of this city is around 4.87 $\mathrm{kWh/m^2/day}$. Beni has medium irradiation according to the classifications of regions related to their irradiation level. This irradiation makes the city of Beni a suitable place to design a solar PV system. [31]. The city has two period wealth particularly the wet (rainy) season which begins around September 15 until May 15 and the parched (dry) season which runs from May 15 to September 15. Midpoint precipitation is around 1027 mm. In addition, its temperature varies between 17 ° 15 'and 20 ° 16'. The average irrigation load means the ampleness of water system is the percent of the field that gets the ideal profundity, or more, of water. The suitable sufficiency of water system relies upon many components and likely changes during the developing season. With an existing irrigation system, if an irrigator increases the average depth applied, more deep percolation will occur. In this thesis we have make the dLQ = average low-quarter depth of water infiltrated $\mathrm{dLQ}\frac{\mathrm{dev}}{\mathrm{da}}x100\%$ of 1hectare which is high than 50%.

4.1.2 Irradiance and Insolation and Pumping Solar Power Plants in DRC

The amount of solar energy that strikes a given area is called "insolation" [32] For any location, the irradiance is given by the equation that follows:

$$Irradiance = \frac{Average\ insolation}{Average\ daily\ bright\ sunshine\ hours} \quad in \quad kWh/m^2 \qquad (4.1)$$

The city of Beni irradiance is calculated by knowing its average solar insolation and its average daily bright sunshine hours. These can be obtained using Table 4-1 and Figure 4-1 related to the city of Beni.

Table 4-1:Monthly Global Solar Insolation of the City of Beni *[32]*

Months	Solar insolation (kWh/m^2)
January	4.9
February	5.17
March	5.03
April	4.93
May	4.80
June	4.81
July	4.90
August	4.92
September	5.00
October	4.69
November	4.64
December	4.69

The yearly average insolation is 4.87 kWh/m^2.

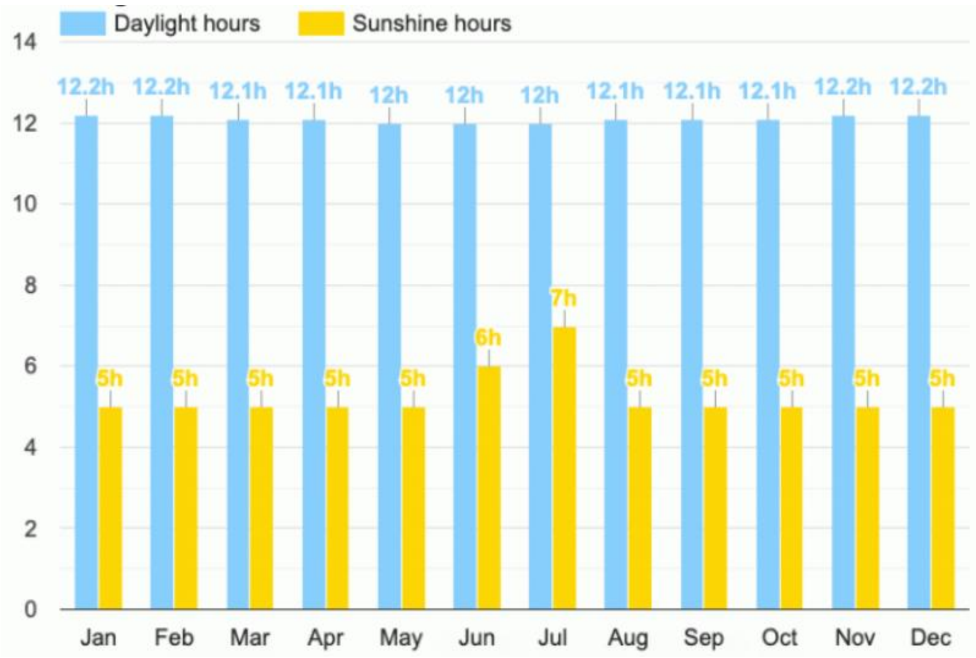

Figure 4-1:Beni Average Sun Hours *[33]*

From the Table 4.1 and the Figure 4.1, the daily average of the city of Beni is 5.25 h means 5h15'.At that point, from the Equation (4.1), we get:

$Irradiance = \frac{4.87\ kWh/m^2}{5.25\ h} = 927.6\ W/m^2$. This value is the irradiance of the city of Beni that will be used in the modelling calculations.

The DRC solar powered potential can be partitioned into three districts (Figure 4.2). Three classes of sun powered illumination are given: Remarkable light in Kolwezi or Lubumbashi (in excess of 2,000 kWh/m2) which is equivalent to the significant assets on the planet like southern Spain or Arizona (USA), great illumination (1,860 to 1,900 kWh/m2) in Bandundu or Kikwit and the Medium light (1,810 to 1,830 kWh/m2) in Goma, Kinshasa and Kisangani, closely resembling the sunlight-based quality in northern Morocco or eastern India. This characterization shows that Solar energy is bountiful in DRC. The Average day by day light is gone from 3.5 to 5.5 kWh/m2. In the southern regions, the normal day by day sun powered irradiance arrives at 5 kWh/m2/day and up to 6.75 kWh/m2. Just in Kasai uniquely in Kolwezi we found information.

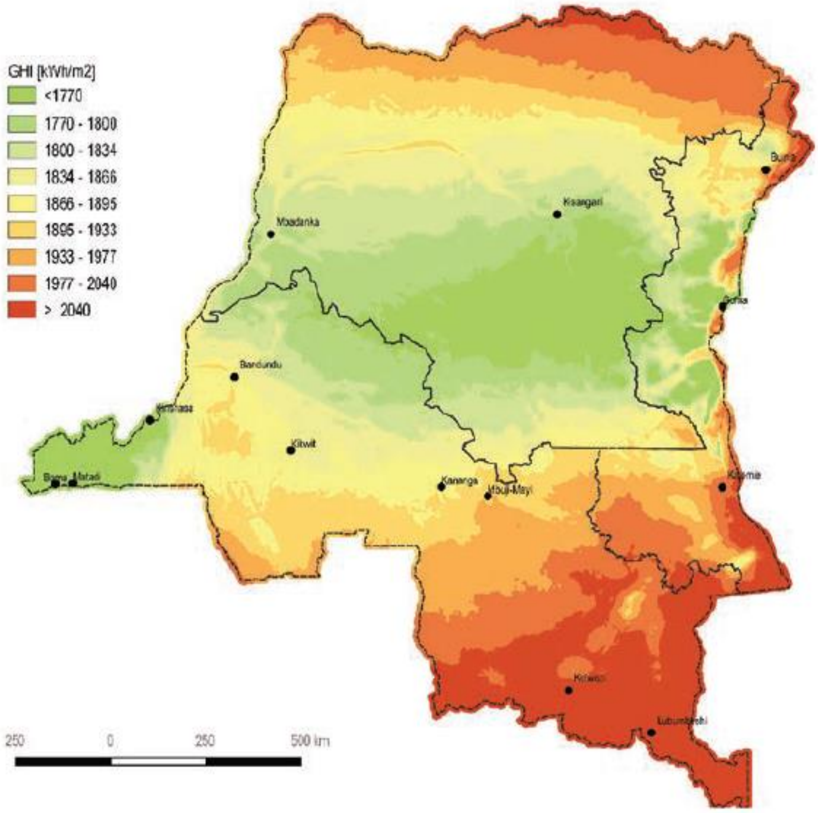

Figure 4.2 Photovoltaic Electricity Potential (GHI, kWh/m2) *[33]*

4.2. Sizing of the Grid-Connected Solar PV Irrigation

After explaining the general scheme of the system, the design was made by the help of element's data collected. It has done and show how to make the integration of source for pumping water [33]. The Table 4.2 shows the parameter selection for the Solar PV system.

Table 4.2 Solar PV Parameter Selection

Fabrication	**JA Solar**
Type	JAP6-72-330/3BB
Model of Technology	Polycrystalline Solar Cells
Module size	0.991 x 1.956 m^2
Weight	22.5 kg
Number of Cells	72
Maximum Open Circuit Voltage	46 Volt
Maximum Short Circuit Current	9.15 Amp
Peak Power	330 Wattpeak
Module Efficiency	17 %

For additional data about the PV module, consult the data sheet in [34]. The favored model inverter for this thesis is Sunny Central 2200 manufactured by SMA.

4.3. Design of Inverter

4.3.1. Role of Inverters

Since the distribution of electric energy is done in AC current, the necessity to transform DC current from PV within AC is mostly required. The device to invert this polarity of power produced by PV is called an 'inverter' [35].

4.3.2. PV Inverters Topology

PV inverters topologies are several according to the requirements. These topologies help to regulate the connection of the photovoltaic modules and the inverter [35]. In Figure 4-3, central inverter (a), String inverter (b), Multi string inverter (c) and Module Integrated inverter (d). Each topology is used depending on design requirements. The choice is depends on the preference by analyzing the advantages and drawbacks of each topology. Some of the popular PV inverter manufacturers are SMA, ABB and Kaco. In this thesis, the Multi String Inverter is chosen.

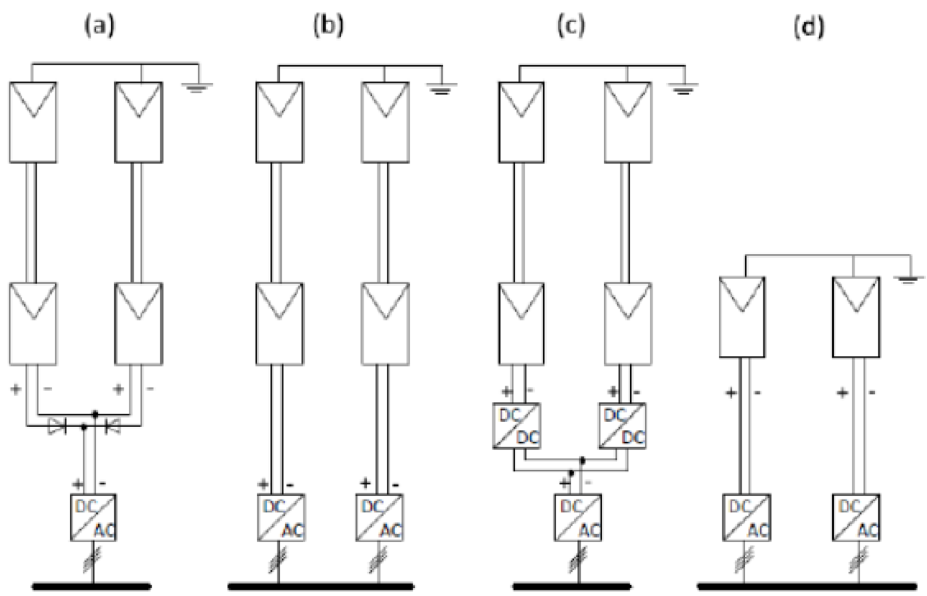

Figure 4-3: PV inverter topologies

4.3.3. Selected Inverter Characteristics

For this thesis, the chosen model inverter is Sunny Central 2200 manufactured by SMA. The leading characteristics of this inverter are appeared in Table 4-3:

Table 4-3: Inverter Characteristics

Applied data	**SC 2200**
Model of Inverter	Multi-String Inverter
Maximum Input Voltage	1100 Volts
Maximum PV Input Current	3960 Amp at 25° and 3600 at 50°
Nominal Output Power	2200 KVA (at 25°)
Nominal AC Voltage	385 Volts
Maximum Inverter Output Current	3300 Amp
Maximum Efficiency	98.6%
CEC Efficiency	98.0 %
Dimensions	2780 x 2318 x 1588 mm
Weight	4000 kg

For other technical data, consult the datasheet [36].

4.4 Irrigation Load in DRC

Irrigation system is basically stunning in the DRC today. Presently, just 73,000 hectares rural land in DRC is inundates, or 0.1 percent of land reasonable for use in cultivating (developed land) well underneath the African norm of 5%. Relative to the whole measure of sustainable water possible, the nation's water pullout is inconsequential. Regardless of the way that the DRC has a water the board, not in the slightest degree of different parts of the institutional design for water system are set up. There clearly to be extensive potential to augment limited scope water system, particularly in the southeast and east as it is displayed in the figure 4.4. A recreation concentrates on lead as a feature of the AICD mull over both benefit making (financial) components and agroecological to discover regions feasible for little and enormous scope water system improvement. Albeit a couple of potential enormous scope water system procedures were bringing up, the related returns were regularly totally low (under 6%). A staggeringly colossal forthcoming (potential) was uncovered for limited scope water system, with 138,000 hectares have the capability of surrender paces of past 12%, and a much sizeable region capitulate positive returns. The most splendid, the utilization fullest regions are situated in the southeast and east districts of the country. The electrical load which will be considered is 10MW.

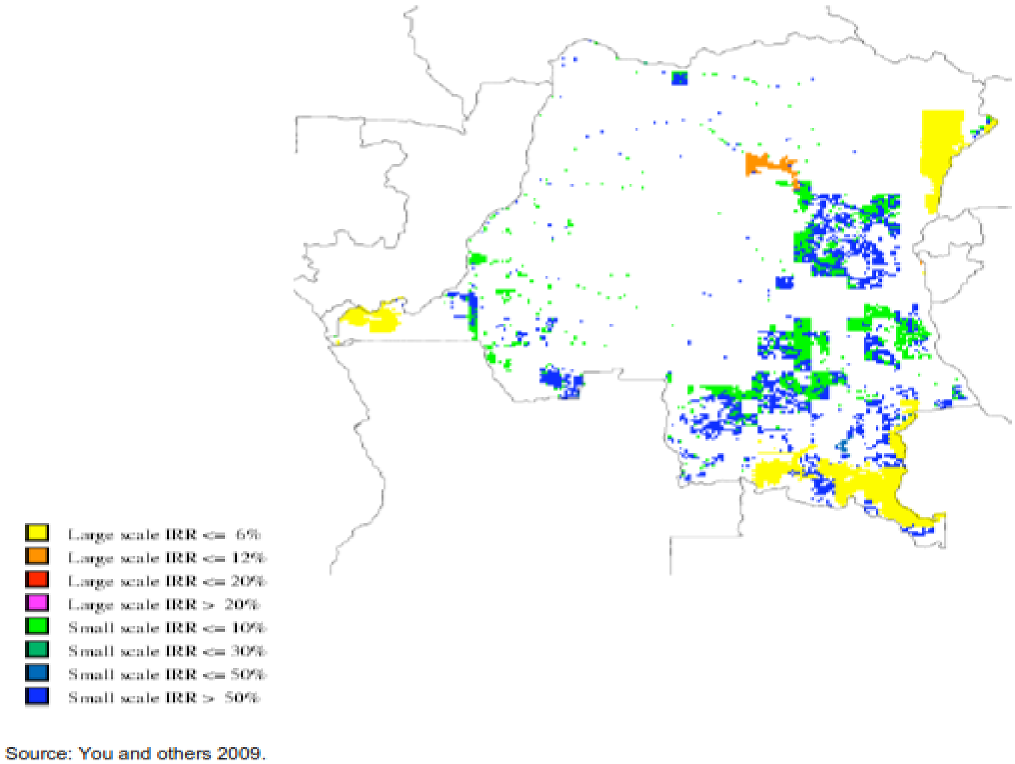

Figure 4.4 **The DRC's irrigation development potential** [37]

4.4.1 Load Determination

4.4.1.1. Motor

At the beginning, pumps were handled by DC engines. Yet, Direct PV generator-engine consolidate where the engine has been of series, shunt, and separately energized DC type have been pondered cautiously along with their specific unique balance and catalyst exhibitions [37]. At the point when these engines are coupled (associated) with a determined voltage source, the withstanding is that the cross-breed framework amusement is exceptionally non-indistinguishable from those gained. Furthermore, when any kind of AC machines is associated with a Grid Connected Solar PV framework it was found that the initial time isn't extensive [38]. The framework feels overwhelmed with need for a modestly lower static force and the framework start off to pivot even at lower insolation level from the sunlight-based side for a smoothed out (streamlined) load trademark (radial siphon). The presence of a MPPT redesign the leadoff (beginning) and firm state amusement of the framework. Then, at that point, it was droned to a nearby that the asynchrony engine was the more sensible for a Grid Connected Solar PV framework since it gives the best supplement the PV hotspot for water system. Here underneath in the Table 4.4 is the model trait of the Motor utilized in this proposition

Table 4.4 Model Characteristic of the Motor [38]

Characteristic	Value	Note
RPM range	From 0 to 6000	Depending on the windings
Nominal power	3 kW	Depending on voltage
Torque	7.6 Nm	For RPM < 1800
Overload	~ 24 Nm	For less than 0,5 Sec. at RPM < 50
Weight	~ 5,8 KG	Including encoder
Voltage	24 V	

4.4.1.2. Pump

For Pumping Irrigation, concerning their heap attributes two sorts of siphons are all around gave over: the diffusive siphon and the volumetric siphon, the volumetric siphons act effectively as a consistent burden while on the opposite the divergent siphon has a procedure or formed flawlessly trademark. It has been portrayed that the energy use of the PV generator by the outward siphon is further developed than by the volumetric siphon [40]. The outward siphon obligations for an amazingly periods in any event, for low insolation levels and its heap trademark is well supplement to the pinnacle power hub of the generator. This kind of siphons is portrayed by its humility, strength permitting long life use and minimal expense. An extra valid statement it was recognized that the productivity of a Grid Connected Solar PV Irrigation siphoning framework is 58.11% for a compressibility siphon and past 86% if a drive (divergent) siphon is utilized. The pace of stream is for the most part repressed by fluctuating the stock recurrence. Subsequently, by the benefit to improve the framework exhaustive proficiency by decrease the inverter power misfortunes, this assortment of siphoning is warmly utilized. Here beneath in the Table 4.5 the datasheet of the siphon model trademark

Table 4.5 The Datasheet of the Pump Model Characteristic [39]

Model	EBARA EVM2 22F/2.2
Rated power	2200 W
Rated voltage	230 V
Rated current	8.71 A
Rated frequency	50 Hz
Rated speed	2860 tr/min
Rated flow	20-60 l/min
Rated pressure	8.2-18.6 bar

4.4.1.3. Efficiency of Irrigation Load

Irrigation systems are rarely 100% productive. The significant ways water can be "lost" from an irrigated field are represented in Figure 4.5. Water is never genuinely lost, however not all applied water is gainfully utilized. For water system frameworks, for example, sprinklers that toss water into the air while flooding, some dissipation happens while the drops are noticeable all around or when they arrive at the yield or then again soil surface. Examination recommends that there is little vanishing of the drop while noticeable all around. Misfortunes to vanishing are for the most part essentially under 10% of the applied water. In the event that breeze blows, beads might be blown outside of the land to be flooded. This is called float. Float misfortunes might be significant and are regularly essentially higher than vanishing misfortunes. At the point when water is applied at a rate that surpasses the invasion pace of the dirt, water starts to aggregate on the soil surface. If the water develops adequately it will start to run off the dirt surface where applied or off of the field. The spillover water could likewise invade at a lower rise in the field prompting helpless consistency of penetration. At the point when water is applied to the field, in overabundance of the dirt water exhaustion (SWD), the abundance water might permeate past the root zone, an amount called profound permeation. Irrigation system that remaining parts in the dirt toward the finish of the developing season may likewise be lost if slow time of year downpours would have recharged the root zone at any rate. Consequently, there are numerous ways applied water can be lost from the plant root zone. The director should limit misfortunes where conceivable, yet constantly a few misfortunes will occur. In this case, the supervisor should realize how much water may regularly be lost with the goal that applications can be acclimated to address plant issues. Application efficiency (Ea) is typically characterized as the small part of the applied water that is put away in the root zone and is accessible for crop water use. In this way, the application efficiency is characterized

as:$Ea = 100\% \frac{dn}{da}$ 4.1

where: E_a = Application efficiency,

d_n= Net irrigation depth,

d_a= Gross or applied irrigation depth.

The Ea can be communicated as either a decimal portion (i.e., going from 0 to 1.0) or a rate (going from 0 to 100%). The applied profundity alludes to the volume applied from the water source separated by the area irrigated by that water. The Ea is the aftereffect of sustem qualities, the executives, soil and yield conditions, and the climate - particularly precipitation. Therefore, there is a wide scope of utilization efficiencies.

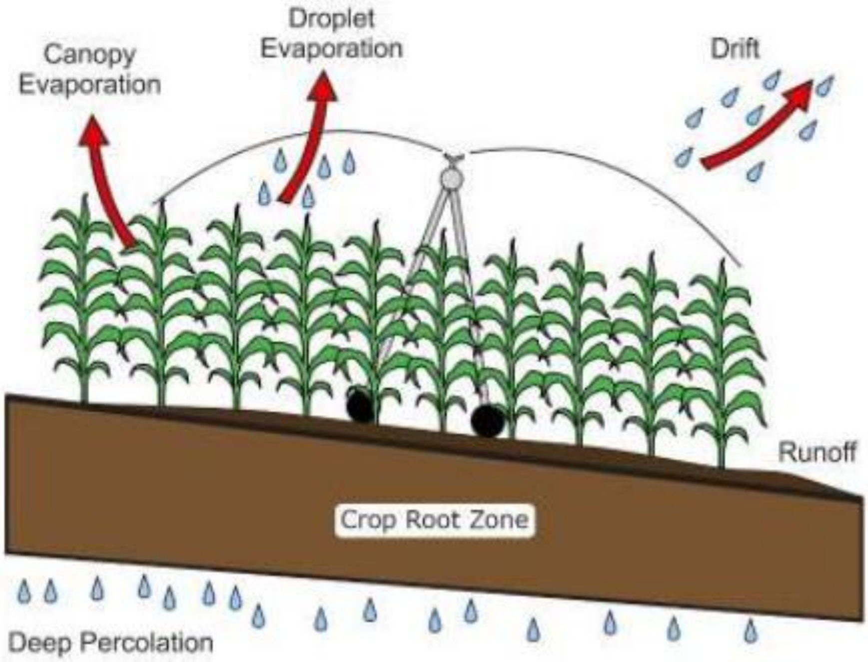

Figure 2.5 Illustration of how water is “lost” from an irrigation system [40]

4.5 MATLAB/Simulink Simulation

The MATLAB/Simulink simulation was carried out by showing the graph of the power, current and voltage at every point of the system. This enabled us to have a look at how the signal is varying depending on the input parameters which are temperature of the PV module and the light emitted (irradiance).

4.5.1 Block Diagram of the Simulated System

In view of this part, the overall system block regarding an MPPT controlled 50KW DC/AC grid connected PV system irrigation is shown. This is shown in Figure 4-6, represents a block layout of the system. By using 50Kw PV group generated with 11 Parallel panels and 21 series. And maximum power is 53KW at 1000W/m2 irradiation. MPP voltage is 850V. The Maximum power is extracted from the PV panel using P&O algorithm at variable solar radiance with a constant temperature of 25^0C. The inverter is used to convert the dc voltage of PV system into ac voltage. The switching frequency of the system is considered to be insufficient as 0.13% compared to 6 pulse and 12 pulses converters. As long as a fewer harmonic is present in the voltage waveform it is affected the reliability and the power quality.

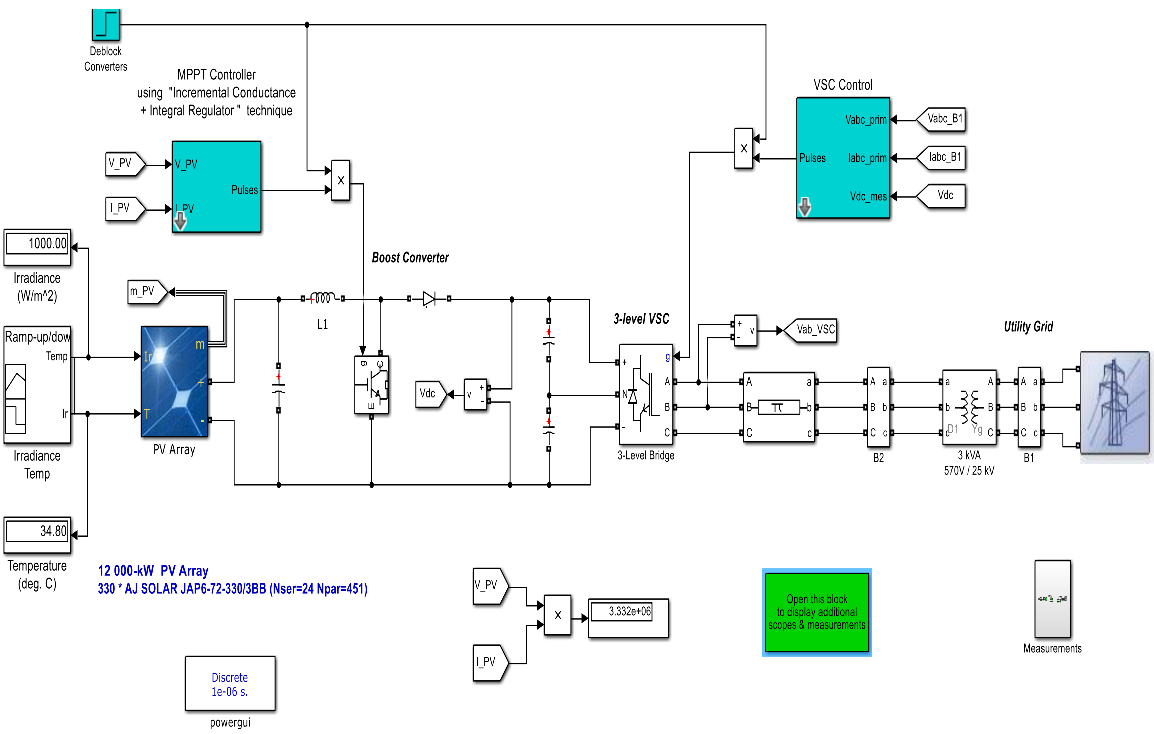

Figure 4.6 Set Block Diagram of the Simulated System

4.5.2. Simulation Diagram of the System

The lower is the irradiation, the smaller current is produced. It is more noticed that the current become greater with enlarging intensity through enlarging the power output of the solar cell. The Figure 4.7 shows the power _voltage and current _voltage characteristics of the PV and it is seen that the power increases as the irradiance increase vice versa. It indicated that the maximum power at 1000 w/m2 is 53.13 kW with a voltage of 850V and the maximum current is 65.78A.

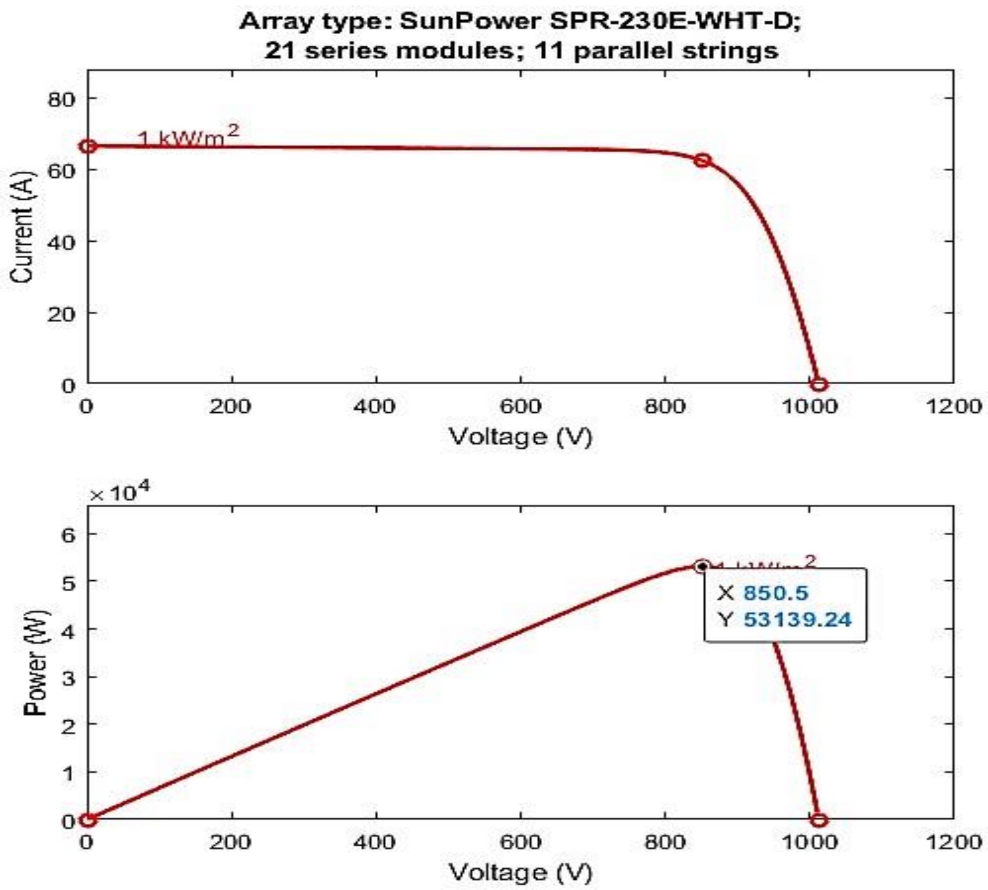

Figure 4.7 Array type at 25°C and Characteristic of I-V and P-V

4.5.3. Irradiation Curve T-Signal Data with 1000W/m^2

The Figure 4.8 shows the signal of irradiation curve. The sunlight with atmosphere absorption which various according to the time. From the morning star up the evening, one side of the curve we have the solar irradiance (W/m^2) and other side we have the time (S). Solar irradiance is the power per unit area awarded from the sun in the form of electromagnetic wave (radiation) as appraised in the understanding range of the averaging instrument. The solar prominence is appraised in watt per square meter (W/m^2) in SI units. Solar irradiance is frequently fused over an allowed time in the way to describe the radiant energy emitted into the neighboring environment (joule per square meter, J/m^2) right away. Then after added to Simulink modeling with the irradiance of 1000W/ m^2 we plot and we found the irradiance, which can be considered in space or at the Earth's surface after aeroscopic involvement and break up. At a lower angle, the light starts at 5 travels through more atmosphere. From the time of transition decreases rapidly with enlarging optical depth, through the day as the sun nearer the horizon there comes a point when transition influence projection for the rest of the day (between 10–15). With a kind of high level of safeguards this can be a significant portion of the late afternoon (between 15-20), the visual depth remainder zero at all altitudes of the sun.

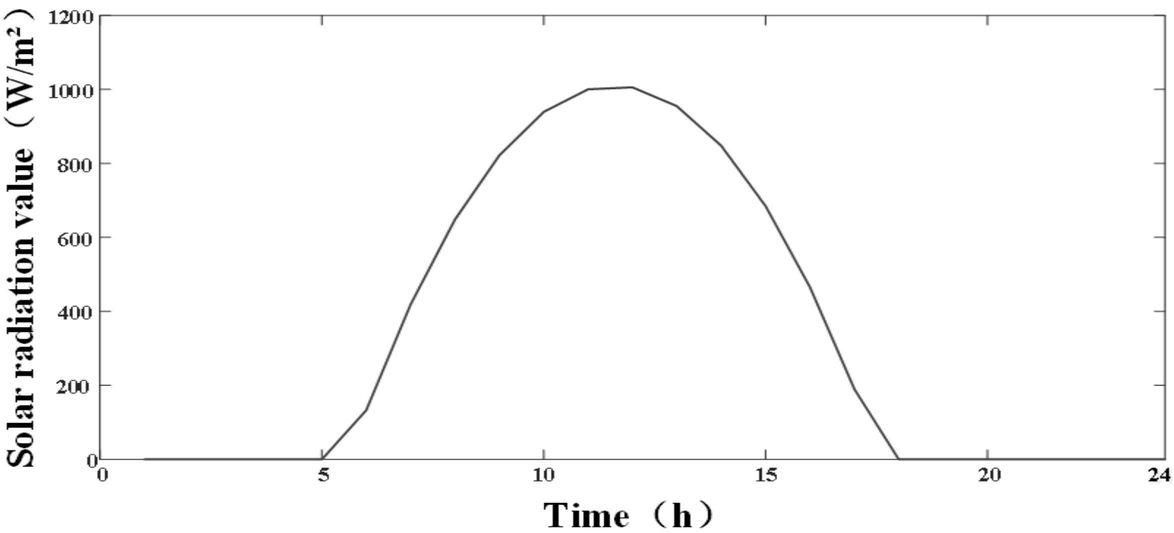

Figure 4.8 Irradiation Curve T-Signal Data with 1000W/m^2

4.6. Modeling of the MPPPT and the Final Characteristic

The MPPT is the most component in the system; it output should be connected to the inverter in other to control the algorithm. The function of the MPPT algorithm is to bring out maximum power from the PV array. We need some measurement points in order to try the system under this irradiation condition. We want to remove some ripples that occur at the beginning of the simulation by using saturations. There is a quantity of different elements influencing grid-connected PV entertainment such us dropping in cables, dropping in the DC/AC conversion by the inverter and it can be allowed on the power level, connecters etc; Tracking systems integrated in the mounting structures can be administrated by detectors or by control algorithms which authorize the automatically command and control of the system. As it is revealed in Figure 4.9. One-cycle (9.52 milliseconds) the power, the voltage and the current data were recorder on the inverter ‘side of the system. It indicated that the maximum power at 1000 w/m2 is 53.13 kW with a voltage of 850V and the maximum current is 63.78A. This experience kicks off at time 0 when a low-voltage event affected the entire PV power plant to catch out. Approximately few minutes later, the plant restart its operation by unhurriedly stepping up its power to the peak power accessible at that time. We have used a THD, which is a common measurement of the level of harmonic distortion present in the system, and in our case is lower 5% for bigger power 12KW. Note that Reactive power is around zero.

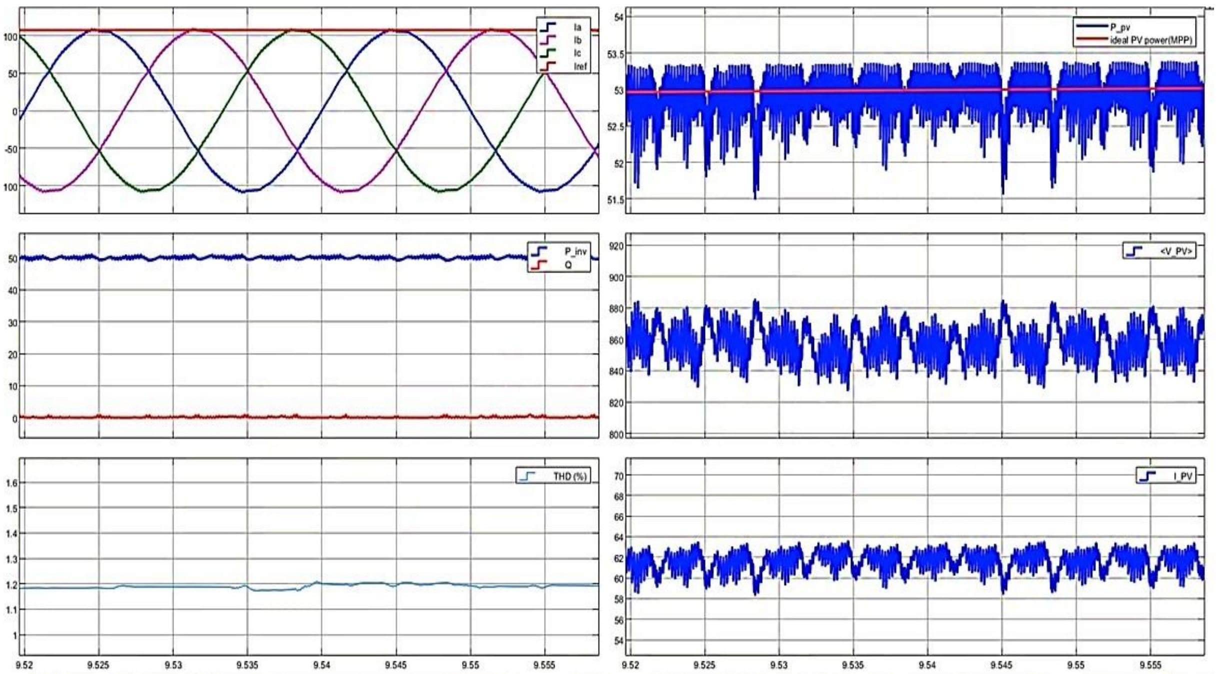

Figure 4.9 Final Characteristic

4.7 The Output Voltage and Current of the Inverter

The diagram shown at the Figure 4.10 and Figure 4.11 consecutively, the result found after integrating the dc source into the inverter, means the output voltage and current result of the inverter before interconnection with the grid. Seeing the Figure 4.10, the event happened and repeated after 0.02 second, when the production of the plant was not far to its highlight value (peak). This experience kicks off at 0 second when evidently a large load stumbled off in power system generating a small voltage transitory subsequently by a speedy rise in frequency. The current has the same form of signal but time difference with that of the voltage (at 0.05 second) because of the load. The plant manages through this high-frequency time period fluently and proceed with generating power, at the same time the control system was navigating the grid frequency back to its ordinary level.

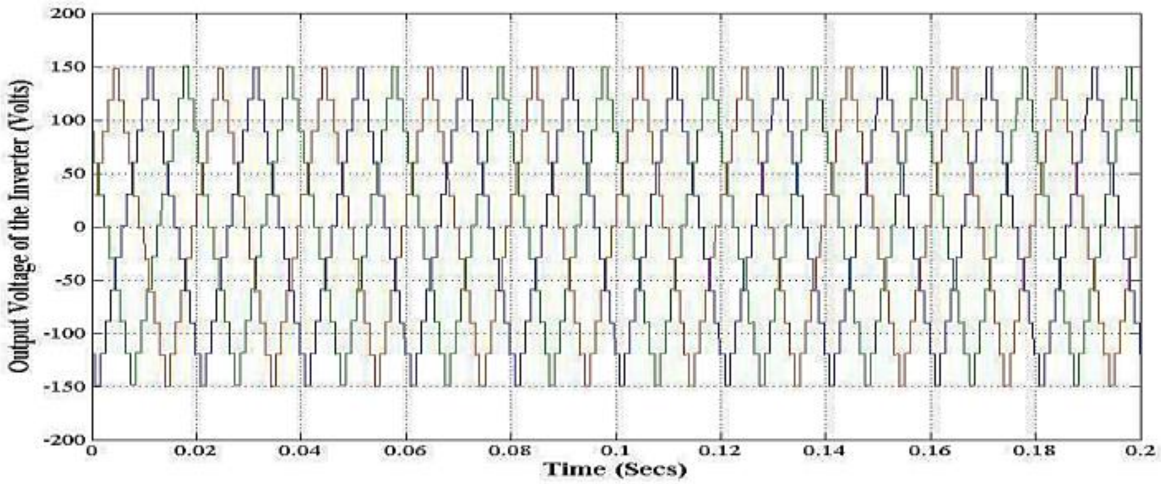

Figure 4.10 Output Voltage of the Inverter

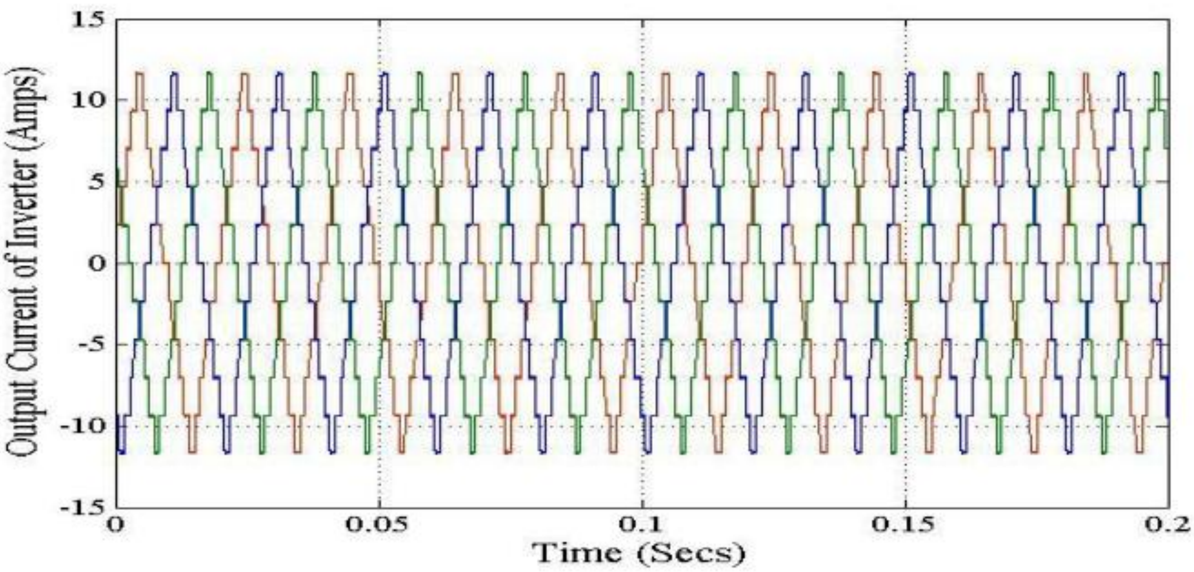

Figure 4.11. Output Current of the Inverter

4.8. THD of the Proposal Inverter

Total Harmonic Distortion (THD) is a deed of harmonic pollution in the power system and it is noticed that dissimilarity in both switching angles of inverter and DC voltages influence the THD of inverter output voltage. The REsource is connected to the grid and also to the 50W three phase resistive load (for Irrigation). It can be perceived that the output of the proposed inverter has insignificant voltage THD of 7.46% and this is acquired lacking the filter. The transformer inductance is adjusted which allow to find a THD at 0.13% which is shown in Figure 4.12. The attained THD is very less compared to that of convention inverter topology because it was lessened. The THD acquired from the phase output voltage of the three phase DC-AC converter was simulated for the mean of comparison with the proposed multi-level inverter. It is remarked that with reduced fundamental voltage, the THD of the output of the three-phase converter is 31% and is very elevated compared to the proposed system.

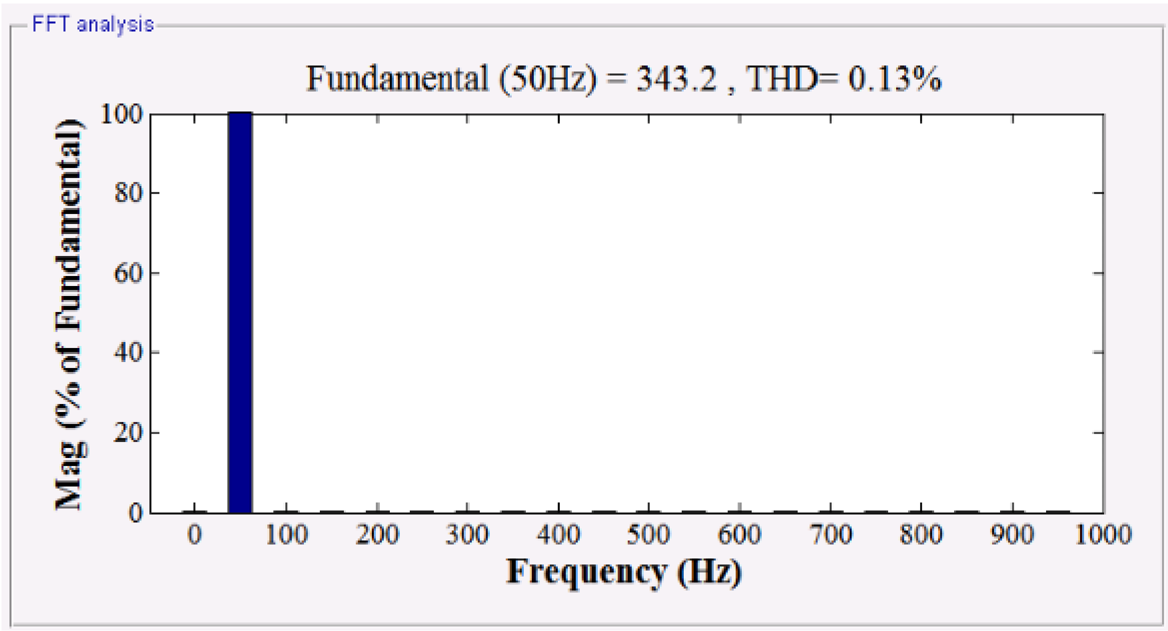

Figure 4.12. THD of Proposed Inverter

4.9 Grid Voltage and Grid Current

The diagram shown at the Figure 4.13 and Figure 4.14 respectively the result of the grid voltage and grid current found before integrating the dc source and make the interconnection. The characteristics of the Electrical grid (voltage and current) varies also with the time of 0.02 second. It has been operated with three phase alternating voltage and three phase alternating current (AC) frequencies synchronized (so that voltage swings occur at almost the same time). At Figure 4.13, the event starts at 0 second and the fluctuations blow at the constantly frequency that why the grid voltage avoid the unbalanced power flow and facilitating energy management of the System (0-400V). At the Figure 4.14, shows current through the resistive load, the grid current signal is shown differently at 0 second because of the active power received and the reactive power absorbed by the grid. The maximum value of the current reach 40 A at the pic and the nominal during working is 20 A.

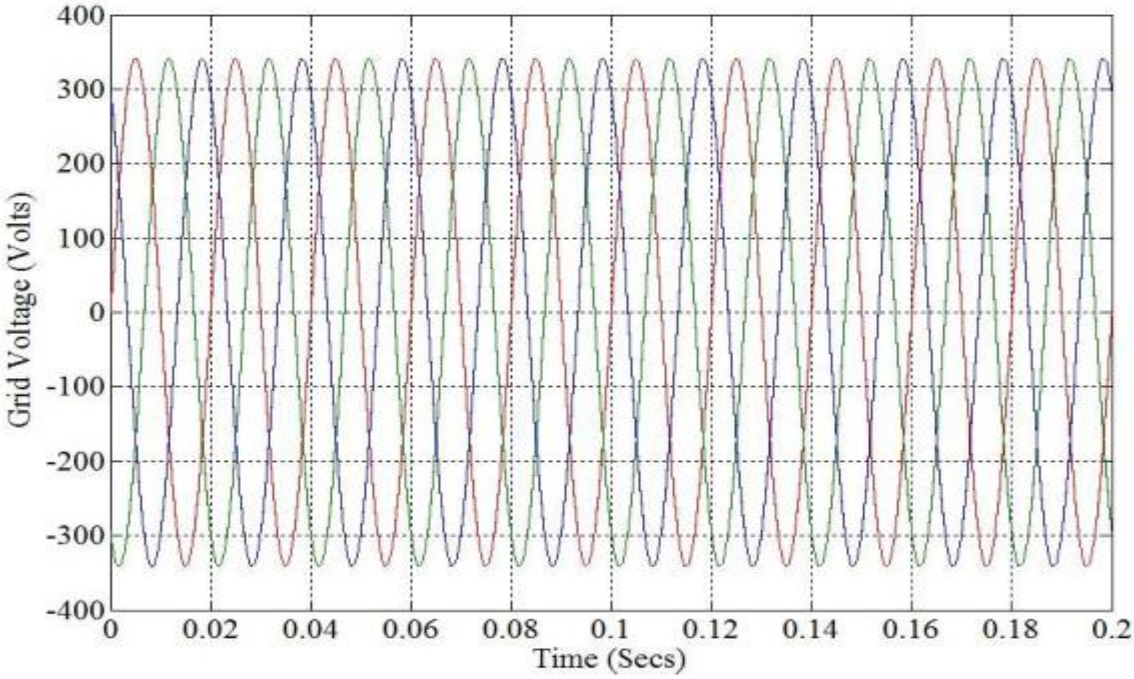

Figure 4.13. Grid Voltage

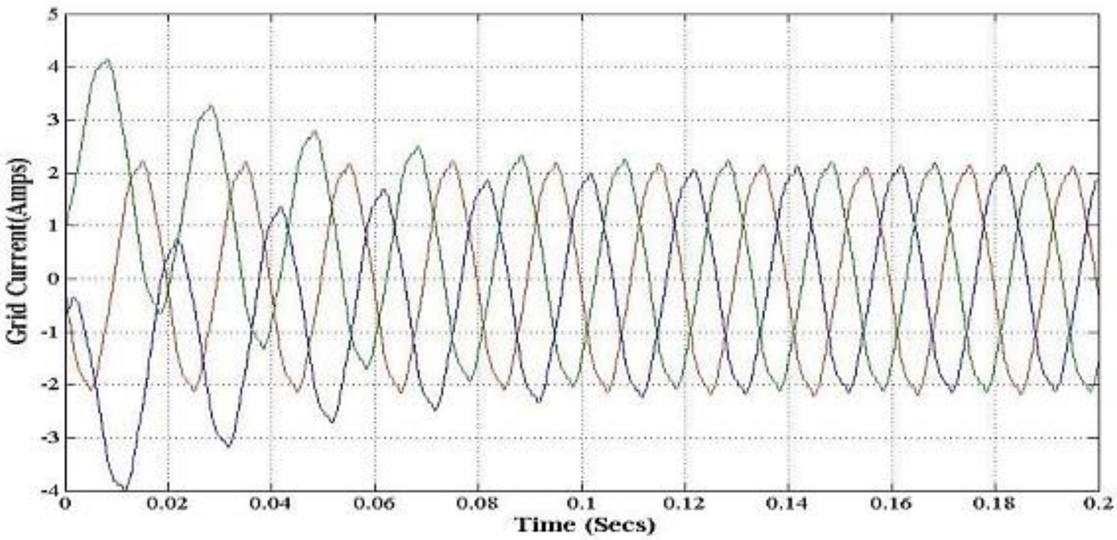

Figure 4.14 Grid Current

4.10 Active Power Received by the Grid

The diagram shown at the Figure 4.15 the result of the active power (368W) injected to the grid. The definite quantity of the power extraction of the PV systems is restricted to a certain extent. The command and the control are engaged to keep away from the overcharging of the grid by guarantee that the peak power inserted by the PV system is inside the power network capacity. This experience attested the plant's potentiality to handle over a low power, in Figure 4.15 as it is shown, the active power absorbed by the grid started degenerate speedily at t = 0.05 seconds, and it hold out its nominal point after roughly 0.3 seconds.

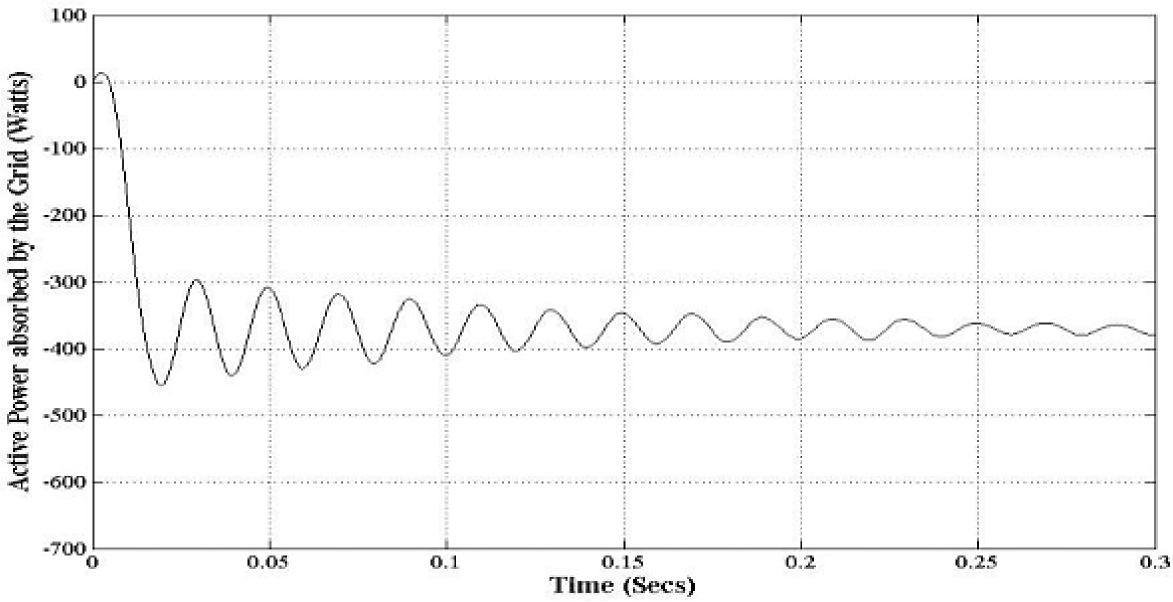

Figure 4.15 Active Power Received by the Grid

4.11 Reactive Power Absorbed by the Grid

At the Figure 4.16, the diagram shows the result of the reactive power inserted to the grid (1082W). When the load current flows through the conductors, the grid consumes reactive power that make up the grid like the conductors. The reactive power improves system factor and to mitigate voltage fluctuations. In Figure 4.16, the event starts at 0 second when the load tripped off, after 0.02 second it is taking the normal fluctuation for the performance, stable, reliable and cost-effective system.

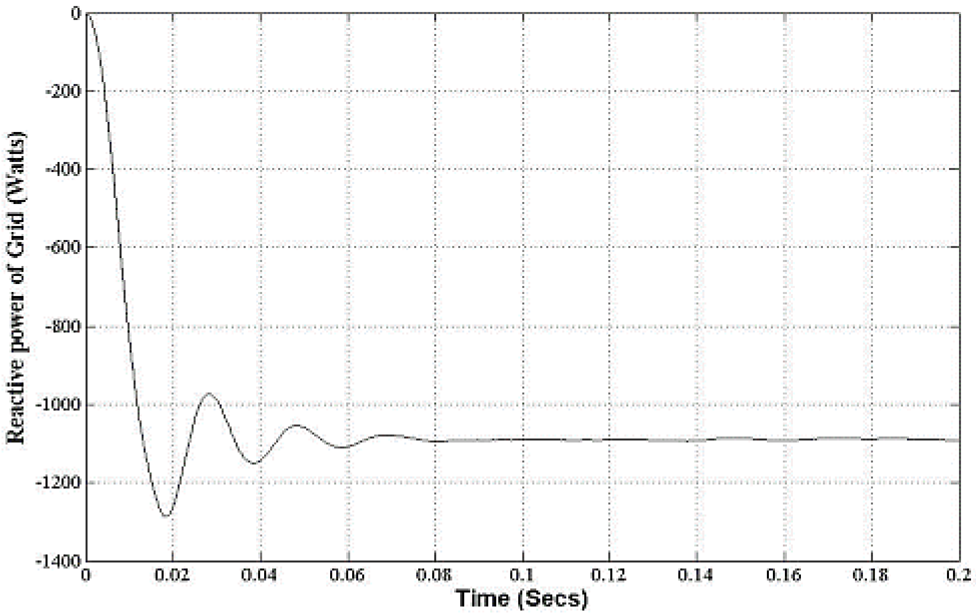

Figure 4.16 Reactive Power Absorbed by the Grid

4.12 Chapter Conclusion

In this section we have shown the Simulation and Analysis of the system from the dc side into the inverter and the output characteristics before integrating with the grid and mate with the load for irrigation. An electrical model of a Grid Connected Solar PV Irrigation is presented using MATLAB for a 50Kw with the solar irradiation and temperature. The results from the MATLAB model show by the help of the MPPT algorithm, which seems responsive to the system needs. The electrical characteristics (Output voltage and current) from the inverter correspondence to manufacturer curves in datasheet, the Grid Voltage and the Grid Current has shown and discussed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

By the end of this work, it is shown that the objectives were attained. The significance of this study consisted to design the simple, efficient and cost-effective system for a hybrid Grid connected solar PV for irrigation using a Perturb and Observe MPPT Algorithm P&O and simulation methods. Electrical parameters from the installed PV modules up to the grid side with the total energy injected to the grid had shown. The methods led to diagram values of electrical characteristics.

The meteorological data or climate data for the city of Beni were considered in the modelling. The irrigation situation data of DRC was found and the electric power needed. A 50KW Grid-Connected solar PV Irrigation was proposed to increase the electricity access rate of farmers in that area, the power quality and increase the farmer's life style. Then it came to an end that the asynchrony motor was the more acceptable for a Grid Connected Solar PV system from the time it provides the best complement with the PV source for irrigation. It was reported that the application of the energy of the PV generator by the centrifugal pump is much elevated than by the volumetric pump. The centrifugal pump works for an extremely long time even for low insolation levels and its charge (load) characteristic is well harmonized with the maximum power point of the generator. This type of pumps is characterized by its strength, hardiness admitting long life use, its modesty and low cost.

The results obtained demonstrated that the project is feasible because of the following facts:

- As there are no more hydroelectric resources near the city of Beni, solar energy is the available resource to interconnect into the Grid and be helpful for irrigation
- The city of Beni is located in the region with a medium level of irradiance in DRC
- During sunshine hours, the energy injected to the grid can be used to supply the loads and in the night time, these will be supplied by the grid.

5.2 Contribution to Knowledge

Design a grid connected Solar PV Irrigation System has been done in DRC for the first time specially in BENI territory. The main contribution of this work is to maintain the reliability for a sustainable system for irrigation to help the population. The use of the modern Power Electronic Device affects positively and efficiently the system. The prompt response by PV inverters makes the system possible to enlarge supplementary advanced controls, to give an example of power oscillation damping stand for that operation mode will be moderately clearly with restrictions made just to a computer and interface software. The study shown us the possibility of the integration of a solar PV power plant through its design using simulation method. The require amount of generation dropping must be transmitted to get involved PV plants as an active power value, so the pre-fault frequency can be rapidly recuperated. The system may be uncomplicated with modern device because of the punctual response times of controller systems and modern inverters. This system has fewer problems for plants that have energy storage.

5.3 Recommendations

In future we expect the Government of the DRC and some investors to focus and invest on solar energy sources for integration with grid for many applications especially for irrigation in Beni territory by building some large-scale PV solar power plant as this energy is the available resources in that area. It is also the energy for future generations. Such kind of projects can increase the electricity access rate and contribute to the sustainable development of the entire nation while becoming a business for potential investors. Controls are presently in existence and needed in much usefulness-scale Grid Connected PV system. It is basically a problem of carrying out controls and/or communications enhance to entirely enable these. The matter in question to be addressed in the process involve compatibility and communications protocol. In the future research, a similar exhibition examination of off-grid and grid connected design plans for different areas with various metrological conditions can be explored. In addition, hybrid system, for example, solar -wind- biomass could be coordinated to inspect the ideal plan. The response by a PV plant have need of occurate tuning of PI controllers for speed response times and keep away from accidental oscillation of the output active power. The PV power plants lacking energy storage have the ability to provide divers services to the grid, but modern interconnection conditions or market mechanisms are required to sort out action for any up-regulation service. This kind of model of power converter and drive is still an opinionated and is conditional on cost and reliability, mostly for applications in which accessibility may be a greatest importance issue; as a matter of fact, there is still a difference of opinion for the direct connected DC motor-pump drive which can be recognized and keep up with very small basic understanding by a local population. Nevertheless, for sites in which communication and proximity is not so much a problem, it would come out that the AC drive solution with proper power constraining will prove to be the best agreement between reliability, initial price, and total energy transporting; that is the case of Grid-Connected Solar PV Irrigation in City of Beni

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Appendix

Modelling of the Irradiation curve

```
clc,clear,close all

N=1501;
R=zeros(602,1
); C=1010;
Co=1; a=13;

d=1:0.1:31;
F=zeros(301,1);

 for
n=1:301
       F(n)=(1-exp(-d(n)^2/a^2))*C+Co;

e
n
d

  for j=1:602
if j<=301
R(j)=F(j);
end       if j>=302
R(j)=F(603-j);
end   end

  IR=zeros(N,1);
    for
n=550:115
1
     IR(n)=R(n-
549);
end
X=1:0.006:10;

plot(X,IR)
```

Modelling of the MPPT Control before the Inverter

```
function Ireference  = MPPT(U,I,deltaD)
% MPPT algorithm
% current
Ireference_zero= 0.1;
Iminimum=0;
I_maximum=150; %this is the inverter maximum current

persistent Vold Pold Iref_old;

if    isempty(Vold)
Vold=0;
   Pold=0;
   Ireference_old=Ireference_zero;
end P= U*I; dU= U
- Vold; dP= P -
Pold; Ireference=
Ireference_old;

if dP~= 0 && U>400
   if  dP
<       0
if dU <
0
         Ireference    =    Ireference_old    -
deltaD;        else
         Ireference = Ireference_old + deltaD;

end
else
if dU <
0
         Ireference    =    Ireference_old    +
deltaD;        else
         Ireference = Ireference_old - deltaD;

end

end
end
%limit the current between minimum and maximum
if Ireference >=
I_maximum
Ireference=I_maximu
```

```
m; end if
Ireference<Iminimum
Ireference=Iminimum
; end

Ireference_old=Ireference;
Vold=U;

Pold=P;
```

Simularity checked

Design of Grid Connected Solar PV Irrigation (DGCSPVI)

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