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ISTANBUL AYDIN UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

CONTROL OF POWER FLOW IN LARGE-SCALE PV MICROGRID WITH ENERGY STORAGE HAVING LOAD CONTROL SYSTEM

MASTER’S THESIS

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Department of Electric & Electronics Engineering
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DECLARATION

I hereby declare with respect that the study “Control of Power Flow in Large-Scale PV Microgrids with Energy Storage Having Load Control System”, which I submitted as a Master thesis, is written without any assistance in violation of scientific ethics and traditions in all the processes from the Project phase to the conclusion of the thesis and that the works I have benefited are from those shown in the Bibliography. (07/07/2021)

Wafiullah FAZALYAR

FOREWORD

I would like to thank the institute of applied science of Istanbul Aydin University, the Department of Electrical and Electronic Engineering, I would also like to thank my family for there endless support, my friends, and every person who gave me any support or advice which helped me in my work.

June, 2021 Wafiullah FAZALYAR

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ABSTRACT

The penetration of distributed energy resources such as solar and wind energies will increase in near future. Microgrids are hybrid structures capable of integrating renewable energy resources with conventional energy generation plants. Microgrids are capable of providing uninterrupted energy for customers. This system has to be run correctly, accurately, and precisely so that power flow in the system is continuous. The thesis demonstrates study of power flow in the microgrid to different loads. In the first place, the Microgrid is simulated in Simulink. Then the obtained results regarding the power flow to different loads are shown in the graphs.

Keywords: Mirco-grid, Grid, Power Flow, Control, Current, Voltage

YÜK KONTROLÜ VE ENERJI DEPOLAMA SISTEMIYLE BÜYÜK ÖLÇEKLI PV MIKRO ŞEBEKEDE GÜÇ AKIŞININ KONTROLÜ

ÖZET

Güneş ve rüzgar enerjileri gibi dağıtık enerji kaynaklarının penetrasyonu yakın gelecekte artacaktır. Mikro şebekeler, yenilenebilir enerji kaynaklarını geleneksel enerji üretim tesisleriyle entegre edebilen hibrit yapılardır. Mikro şebekeler, müşteriler için kesintisiz enerji sağlama yeteneğine sahiptir. Sistemdeki güç akışının sürekli olması için bu sistemin doğru, doğru ve hassas bir şekilde çalıştırılması gerekir. Tez, mikro şebekedeki farklı yüklere güç akışının çalışmasını göstermektedir. İlk olarak, Microgrid Simulink'te simüle edilir. Daha sonra farklı yüklere güç akışı ile ilgili elde edilen sonuçlar grafiklerde gösterilmiştir.

Anahtar Kelimeler: Grid, Akış, Voltaj, Micro-grid, Kontrol

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ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
ESS	Energy Storage System
MPPT	Maximum Power Point Tracker
PV	Photo Voltaic Panel
PWM	Pulse with Modulation
SPWM	Sinusoidal Pulse with Modulation

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I. INTRODUCTION

A. Introduction to Power Flow in Micro-Grid

Constant development in society and advancement in machinery have raised the need for electricity requirement. This caused usage of electricity to the level that may no longer be manageable if its modification is ignored. This is an alerting condition for finding ways to provide sustainable energy to meet the demand. Approximately 65–75% of all energy is consumed in urban areas which are responsible for more than 75% of greenhouse emissions (Mohanty, Choppali, & Kougianos, 2016:60–70; Nam, & Pardo, 2011:85-94). Traditional, centrally controlled systems for the distribution of electrical power are being used for a long time, named the power grid. These common power grids are capable of performing only some basic functions like power generation, distribution, and control of electricity to a little extend (Fang, Misra, Xue, & Yang, 2012:944–80). These grids have high transmission loses and has low reliability, and power quality. Considering these problems requires complete modification of the power transmission system. In nutshell, we have two main reasons one: very little losses, and second: the environmental aspect for introducing ‘smart microgrid concept. Efficient utilization of electricity alongside power with greenhouse gases will help us to live in a more clean and attractive environment. Micro-grid has a better solution for the generation of electric power and a useful method for the distribution of the available power. It can be easily installed; low maintenance cost requires less space. The goal of this system is to provide high controllability, high performance, and high security of power system (Osama, Muhammad, & Tallal, 2020).

B. Large-Scale PV Microgrids with Energy Storage Notion

There is no exact beginning of the Smart grid system. This notion started with the beginning of concerns about certain aspects of the traditional grid such as control, reducing costs, and distribution of electrical power to the rural areas. Its usage dated back to the 1975s and 85s. At that time, they were used to achieve information of consumers on the grid side (The History of Making the Grid Smart, 2018). But the most fundamental need still under consideration is reliability and highly efficient power transmission and distribution. The recent step in the modification process of the grid is that it should not only be bounded to distribution and transmission but able to be geared with clean renewable energy resources, so to decease environment contaminating particles and gases.

C. Inspiration

As it is mentioned the traditional grid is not capable of solving the upcoming global problems such, urbanization, increasing power demand at the consumer's side, distributing energy to the rural zoon's.

The traditional grid also some internal problems, that are no more tolerable such as high losses, low controllability, contaminating the environment, security problems.

In a nutshell, we need a whole new approach to power distribution, which is known as Micro-grid.

D. Importance

Micro-grids require a whole new approach of modification to enhance grid reliability, make it less vulnerable, the need for the environment preserving, energy conservation, improve internal efficiency, and consumer services.

II. MICRO-GRID DESCRIPTION

Photovoltaic System: Photovoltaic (PV) is designed to generate electricity from solar energy in a beneficial way. These devices generate electrical energy directly from sun radiations via a natural electronic process that takes place in semi-conductors. Today many of our instruments and gadget are operated by PV energy, for example, calculators, traffic signs, radios, house lighting, air-condition, fan, solar heating system, also used in spacecraft, and residential elevators, and many more. The efficiency of Solar cells is variant and finding specific efficiency is challenging because of the reflection of rays and losses in the converting process of energy (Photovoltaic (Solar Electric)).

A. Micro-grid

Micro-grids which is going to open a whole new chapter in the history of traditional grid. In the near future old grid will not be capable of meeting the consumer demand. Micro-grid will sooner replace to traditional grid to meet the demand. Furthermore, micro-grids more resistant to failure, high safety, highly efficient, very low transmission cost, consequently low due bills to customer.an updated apparatus which will allow two directional energy and data flow (Asia, & Sahar, 2017).

1. Micro-grid Advantages

- Allows plug and play, very easy to use.
- Allows high quality, high reliability.
- Allows More control on balancing supply and demand.
- Allows meter that are in communication with load and grid
- Allows to manage and optimize site’s energy consumption and to cut costs
- Allows self-correction, Self-monitoring, and restoration.
- Provides more flexibility to customer by giving more choices (Asia, & Sahar, 2017).

2. Comparison Between Grid and Smart-Grid System

Table 1 Micro-grids vs Traditional-grid

Micro-grid	Traditional Grid
1) Bi-directional communication between customer and grid. 2) Interdependence Network system. 3) A large number of sensors are involved. 4) Digital data transformation. 5) Automatic Control. 6) Extensive Control over grid. 7）Vulnerable to fiber attacks, which causes security converns.	1) Mono-direction communication. 2) Radial Network. 3) A small quantity of basic sensors are used. 4) Mechanical Operation. 5) Manual Control and Monitor. 6) Limited control. 7）No security or privacy concern

3. Classification of Micro-grid

According to bus connection, Microgrids can be classified into 3 types, bus connection is based on the load type, for example, if we have a dc load, then we will use conversion in such a way that we end up with dc bus, and the same is for AC loads.

AC Micro-grids: AC microgrids can be easily combined with the traditional AC grids if we have an AC load. all the energy flow to load will convert to AC power for example if an AC load is supplied by PV sources, or battery we use DC to AC converter to make load and source-compatible. As a result of this conversion, a big portion of the energy is lost, in converter components.

DC Micro-grids: The connection process is much similar to as AC Micro-grid. In this we have a little conversion, consequently high efficiency, we only need to boost the available voltage from the PV source, to do this we use a DC-DC boost converter.

Hybrid Micro-grids: This Mirco-grid has high flexibility due to its availability for connecting both alternating current load and direct current load, which means it combines both ac and dc grid together.

4. Classification of Micro-grid Due Its Operation Mode

a. Dependent Mode Grid Connected Mode

In this mode Micro-grid is connected with traditional grid, not only connected but always in bi-communication with the normal grid, which means during the high power demand from the load side when the renewable sources cannot meet the demand, the grid supports the Micro-grid and meets the over demand, while in low demand when the renewable energies are generating more energy than the Micro-grid is in communication with the grid and sell the extra power to the grid, consequently bring benefit to the costumer side.

b. Independent Type

This type of Micro-grid is not connected with the traditional grid but works independently, basically, this is used in rural areas where the distribution of grid energy is very costly or hard to reach, all the renewable energy sources such as solar, wind, biomass are connected with the Micro-grid.

The microgrid consistently works on its own when disconnected from the utility grid, it is not difficult to island it, by opening the circuit breaker at PCC we can disconnect it. As all the suppliers are renewable sources, it's very cheap, and many technical problems can occur, which causes high maintenance cost.

Fundamental challenges of islanded mode:

- Conversion of power from Energy storage decive mostly battery.
- Decentralized method of control design.
- Refining the power generated by renewables, which is deteriorated due to disturbances.

B. Energy Storage System

For a better operation of standalone microgrid requires an energy storage system, for some economic reasons batteries are used. It is needed to use energy storage system (EES) in oder to supply consistent energy to demand during the occurrence of disturbances or maintenance is taking place.

It's also worth to be mentioned that EES is good for efficient usage of power as when PV is on its high performance and generates more Energy than need that can be stored in the EES and used later.

Energy storage systems can be classified into three types:

- Electromechanical such: Batteries
- Kinetic Energy Storage such as Flywheel
- Potential Energy Storage (Yoldaş, et al., 2017:205-214) such as Pumped hydro and air storage that is compressed (Yoldaş, et al., 2017:205-214)

Battery:

Battery are cheap, so mostly we use batteries

Flywheel:

Flywheel has long life time high-power capacity but they expensive.

Pumped hydro and compressor air storage:

Renewable energy systems equipped with batteries to suppress and mitigate energy supply problem, however have two major disadvantages (U. S. D. o. E. b. L. S. Communication, 2018):

- It causes high cost for the whole system
- Batteries has the minimum life time compared to the other components used in the micro-grid, the compels the continuous maintenance.

However, there are some other methods that eliminate the usage of batteries or any other expensive energy storage devices, which are known as sliding mode controllers. This mentioned controller is used to control the energy harvested from solar cells in a dependent mode. In this controller, we use a buck converter. It has two working modes:

- If we have more energy generation than demand, in that case, the converter operates under the maximum generation mode, which means lower than MPPT.
- If we have less energy generation than demand then the converter will cause the system to work on its maximum performance.

III. MODELING PHOTOVOLTAIC SYSTEM (PV)

A. PV Modelling

A PV cell consists of DC current source, a diode in parallel but opposite direction of the current source normally p-n junction, a shunt resistor, and series resistor as represented in the figure 3.1 (Yagmur Kircicek, 2014). This DC current source is naturally reactive to the strike of sun rays, when sunbeams hit the surface of solar cell it releases DC current (Savita Nema, 2010: 487-500; Amatoul, 2011).

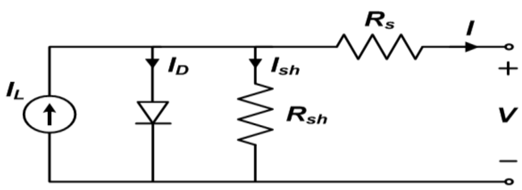

Figure 1 Photovoltaic equivalent circuit cell based on single diode model

We use Kirchhoff's current law to find photovoltaic output current. The final equation (Tjukup Marnoto, 2007),

$$I_{pv} = I_{ph} - I_d - I_p$$

Equation 1

Where $\boldsymbol{I_{pv}}$ is the cell current, $\boldsymbol{I_{ph}}$ is the photovoltaic output current, $\boldsymbol{I_d}$ diode current, $\boldsymbol{I_p}$ is the parallel resistor current

$$I_d = I_0[e^{\frac{V+IR_S}{V_T}} - 1]$$

Equation 2

$\boldsymbol{I_0}$ saturation current, $\boldsymbol{R_s}$ serial resistor, $\boldsymbol{V_T}$ thermal voltaj $\boldsymbol{K}$ is electron charge constant, $\boldsymbol{T_c}$ is actüal cell temperature.

$$V_T = \frac{KT_c}{q}$$

Equation 3

$$I_{ph} = \frac{G}{G_{ref}}(I_{ph,ref} + \mu_{sc}\Delta T)$$

Equation 4

The above equation G the irradiance, $\boldsymbol{G_{ref}}$ is the irradiance at standard-test-condition (STC), $\boldsymbol{I_{ph,ref}}$ is the photo current at standard test condition , T is the temperature of cell (STC).where $\boldsymbol{I_{ph}}$ is based on the temperature degree and flux of irradiance.

$$I_p = \frac{V + R_s I}{R_p}$$

Equation 5

is the resistor current in the equivalent circuit shown above. The PV system's final equation can be seen below.

$$\mathrm{I} = \frac{\mathrm{G}}{\mathrm{G_{ref}}}\left(\mathrm{I_{ph,ref}} + \mu_{sc}\Delta\mathrm{T}\right) - \mathrm{I_0}\left[\mathrm{e}^{\frac{\mathrm{V+IR_S}}{\mathrm{V_T}}} - 1\right] - \frac{\mathrm{V} + \mathrm{R_s I}}{\mathrm{R_p}}$$

Equation 6

This identical circuit diagram is shown is for a single cell, thus needs modification in the number of parallel cells which increases the amount of current and Ns (number of series cells) which correspond for voltage, that them into accounts then array current is given below:

$$I_{pv} = N_p I_{pv} - I_0[e^{\left(q\frac{\frac{V_d}{RI} + \frac{R_s I}{R_p}}{N_s KFT_{pv}}\right)} - 1] - \frac{\frac{N_p V_d}{N_s}}{R_p}$$

Equation 7

B. PV Simulation

We ignore the losses in PV systems. At every certain moment, there is maximum availability of power generation from the PV cell which is known as (MPP). The best method for computing this MPP is using short circuit current (Isc) and open-circuit voltage (Voc). The module created has 29 cells in series connection type, and one cell 0.6 V, so 29*0.6= 17.4V (Kashif Ishaque, 2011).

The PV module includes three subsystems that are shunt, parallel but opposite to current direction diode and phase currents. Matlab Simulink PV block has two inputs, one input is for irradiance, we can provide constant irradiance as well we can provide variable irradiance using Excel sheet. Another input is for the temperature of the environment. Moreover, we can select a number of modules (For increasing the current) and also increase or decrease the number of the series module (For increasing the voltage). Using this way we can array almost similar conditions as in reality. the following figure shows I-V and P-V curves obtained for our project, figure 2.

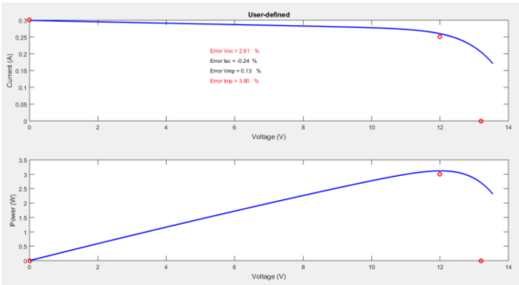

Figure 2 I-V and P-V Curves

The sizing for the PV module was done according to DC bus requirements that are based on the battery nominal, and charging voltage, as well as considering the output voltage of other renewable distributed energy resources. We can adjust the voltage and current by increasing and decreasing the number of the parallel modules and series strings (Ishaque, 2011).

Table 2 PV Specifications

Open Circuit Voltage	Voc	13.2
Short Circuit Current	Isc	0.3
Voltage, Maximum Power	Vm	12
Current, Maximum Power	Im	0.25
Maximum Power	Pm	3

C. Maximum Power Point Tracking (MPPT)

The maximum power point tracker is a DC to DC converter that optimizes the output voltage of solar PV panels. Utility Grid and energy storage systems are all communicating in such a manner that operates the PV with a method that gives the highest efficiency of the solar energy system (Cullen, 2014). To attain the highest suitable power from PV systems Maximum power point tracking is the best choice. MPPT controls the PV output, then compares it with the voltage of the battery, and deals with the power so that not only does it satisfy the load but also charges the battery (Leonics, 2016). MPPT improves the solar energy generated electrical output much efficiency compared with non-MPPT systems.

1. Incremental Conductance MPPT Algorithm

Incremental Conductance method uses the data of source voltage and current to find the optimized desired operating point. From the P-V curve of a PV module shown in Fig 2 it is understandable that slope is zero at maximum point (Dhananjay, & Anmol, 2014: 123-132; Al-Bahadili, Al-Saadi, Al-Sayed, & Hasan, 2013: 79-84). So, the formulas are as follows.

$$\frac{dP}{dV}\mathrm{mpp} = \frac{d(VI)}{dV}$$

Equation 8

$$0 = 1 + V(\frac{dI}{dV})\mathrm{mpp}$$

Equation 9

$$(\frac{dI}{dV})\mathrm{mpp} = -\frac{1}{V}$$

Equation 10

Equation 10 is the condition to achieve the maximum power point, when the variance of the output conductance is equal to the negative of the output conductance, the module will work at the maximum power point (Safari, & Mekhilef, 2011: 1154-1161). The flow chart of the incremental conductance is shown in Fig 3.

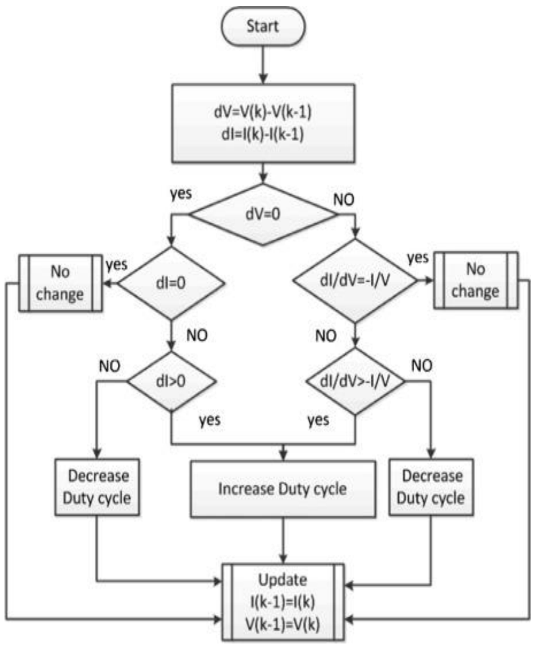

Figure 3 The flow chart of the incremental conductance

D. DC to DC Boost Converter

The following diagram demonstrates a DC_DC boost (step-up) converter, the source Vs is 12V, the output voltage Vo of 17V this is because to charge the battery, output power P_o of 100 W with the efficiency and system frequency 25 kHz, respectively. The inductance L and capacitor C should be calculated (shown in appendix A) to fulfill the required condition following the equations from 11 to 14.

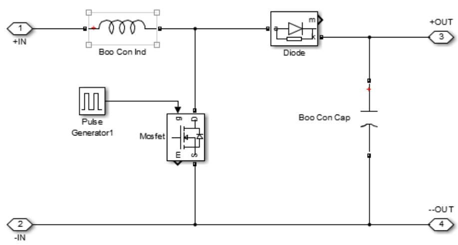

Figure 4 DC-DC Boost Converter

$$D = 1 - \rho(\frac{V_{in}}{V_o})\rho$$

Equation 11

$$L >= D\frac{(1 - D^2)R}{2f}$$

Equation 12

$$C >= \frac{D}{R(\frac{\Delta V_{out}}{V_{out}})f}$$

Equation 13

$$R = \frac{{V_{out}}^2}{P_{out}}$$

Equation 14

D ⇨ Duty Cycle.

V_{in} ⇨ Input voltage to Dc to DC step up converter.

V_{out} ⇨ On put voltage to Dc to DC step up converter.

L ⇨ Inductance of the DC to DC step up or boost converter.

C ⇨ Capacitance trance of the DC to DC step up or boost converter.

R ⇨ Resistor.

ΔV_{out} ⇨ Maximum ripple voltage desired

F ⇨ Switching frequency which (In the project) used (25 KHZ).

E. Battery System

1. Battery Model

Battery plays an unignorable role in electrical systems, especially when PV or grid has no supply. The electromechanical battery has dominated the market. We cannot avoid the importance of battery, because it plays irreplaceable device in our day life, we have them in laptop, mobile phone, elevators, and almost every gadget (Al-Bahadili, Al-Saadi, Al-Sayed, & Hasan, 2013: 79-84). We can also think of it as a converter of energy type, during extra energy it store electric energy, and upon need it gives back the stored chemical energy in the form of electrical energy (Yuriy, & Mikhaylik, 2004). Here we use the lithium-ion battery for this project as this battery has important benefits in comparison to other types of batteries in many aspects for example it has higher power desity, due this property lithium-ion battery can store more energy, control higher voltage and many more 3.5.

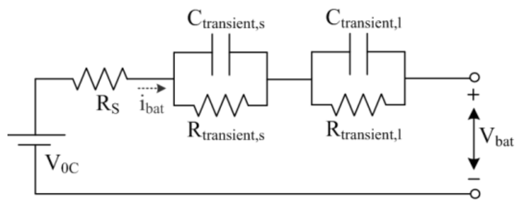

Figure 5 The equivalent circuit battery

a. Battery Model Includes Three Portions

Open circuit voltage, ohmic resistance, and two resistive capacitors in parallel network shape. The voltage of the resistor-capacitor yields the battery's transient voltage response and shows the dynamic in the electrode electrolyte interface. The equation given below show the computation of each rc circuit voltage (Electronic Notes).

$$\mathrm{I} = \frac{\mathrm{V}}{\mathrm{R}} + \mathrm{S_{cv}}$$

Equation 15

$$I/_{sC} = \frac{V}{sCR} + V$$

Equation 16

$$I_p = \frac{V + R_S I}{R_p}$$

Equation 17

F. Utility Grid

1. Source

This Project is design for small DC load in residential apartment, where the supply is 220V from utility.

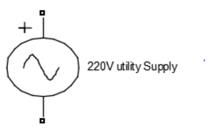

Figure 6 220 V utility supply

2. Load

We have DC load, that exist at the end of the AC supply. In this project the load is 2,17R as per calculation done in the mentioned part.

Figure 7 DC load

3. Control System of Load Changing in the Grid

An electronic Load Controller (ELC) is an energy or more precisely power electronic tool mostly used instead of a regular speed governor for managing the frequency of the load. The fundamental functioning role of ELC is dumping the extra energy generated when the customers turn off their loads, to keep a constant load on the generator. These loads that work to dump the extra load are known as dummy loads. Currently used ELCs have two equipment to accomplish these tasks, one as mentioned before dummy loads and others are three switches for controlling the power of every phase. Every phase is equipped with one dummy load and one single power electronic switch. This results in a significant decrease in the component count and the adjoining costs. Switch to dump power from each phase to the dummy loads (Singh Bisht, Sood, & Nikhil, 2012; Rajendra, Rojan, & Indraman, 2013).

Fig. 5 depicts the diagram of a famous form of electronic load controller, alternating current Voltage Controller based ELC, implemented with the generator. In this class of ELC, the dummy load is attached with the customer load, as well as a pair of anti-parallel thyristors. The interesting thing about the thyristor is that it controls energy consumption by changing the firing angle(alpha) (Singh Bisht, Sood, & Nikhil, 2012; Rajendra, Rojan, & Indraman, 2013).

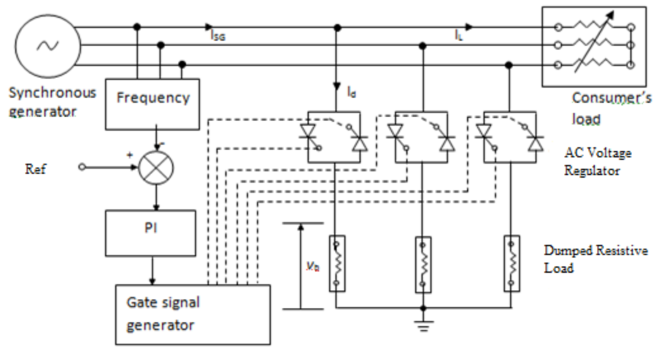

Figure 8 Detail circuit diagram of ac voltage controller based ELC

4. Transformer

For properly feeding out load supply and without any damage to the load we have to we need two things.

- DC supply
- Reducing the source voltage. Transformer will help as to reduce the power supply.

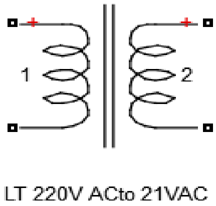

Figure 9 LT 220V AC to 21VAC power supply

5. Rectifier

IF we have alternating current load then we must supply AC voltage and current, nowhere rectifiers come into the picture, the rectifier uses four diodes to change AC current to direct current. This rectifier is commonly used as a bridge rectifier because the diodes are in a bridge configuration. Now normally we use low DC voltage to the load, so first, we reduce the AC voltage using the transformer that alternating voltage provided as input to bridge rectifier and this rectifier will change out AC to 14.7VDC as shown in Figure 8.

6. Capacitor Smoothing

Now to reduce these ripples to the lowest amount smoother capacitor comes into picture, which is connected in parallel shape with output of the rectifier as shown in figure 8.

Here is how the capacitor smoothest the voltage: when the rectifier voltage is high, then the capacitor is charged and futher power is delivered to the load, when the rectifier voltage decreases from the voltage of capacitor then capacitor discharges its stored energy to the load, the diode are in such a configuration, so the back flow of voltage to the rectifier is impossible until the diode are broken.

This is the magic behind the smoothing capacitor, capable of providing current while it is not available from the rectifier, and accordingly the voltage varies considerably less than if the capacitor were not present.

We can never completely remove ripple from the direct current after rectification and smoothing, which means there always be some ripple, but we can reduce the ripple size and amount using higher value of the capacitor, the capacitance the higher the smoothing (Singh Bisht, Sood, & Nikhil, 2012).

It must be mind that the diode not only changes AC to DC but also prevent the flow of current from the capacitor to the input side.

The selection of the capacitor value needs to satisfy a number of demands. fundamentally, the number of capacitors should be selected in such a way so that its time constant is much longer than the time interval between the successive peaks of the rectified waveform:

$$R_{load} * C \gg {}^{1}/_{f}$$

Equation 18

Where:

R_{load} = This is the costumer side complete load

C = value of capacitor in Farads

f = This f represent the ripple in Hz the frequency is normally two times the line frequency a full wave rectifier is used (Singh Bisht, Sood, & Nikhil, 2012).

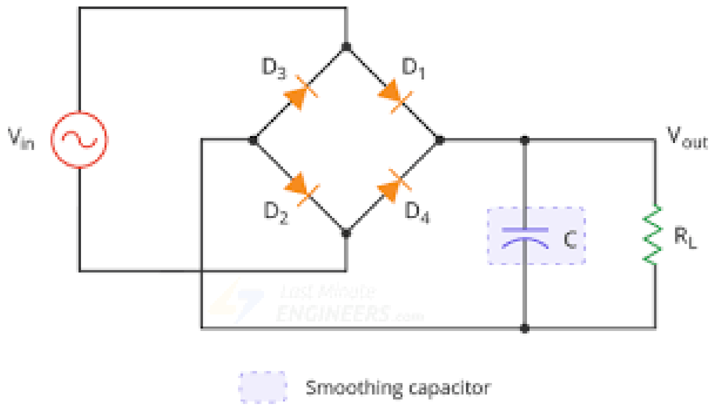

Figure 10 Full-Wave rectifier with Smoothing Capacitor

IV. METHODS AND FINDINGS

A. Grid Supply

This micro-grid is designed for DC load. We have dc bus supply. We need to change AC bus supply to DC. The calculations of the transformer diode and related stuff are mentioned in the appendix A here is the grid with the rectifier shown in the figure 1 below. The grid will the supplier to the load when PV can not supply the load and the state of charge of the battery is less then 40%.

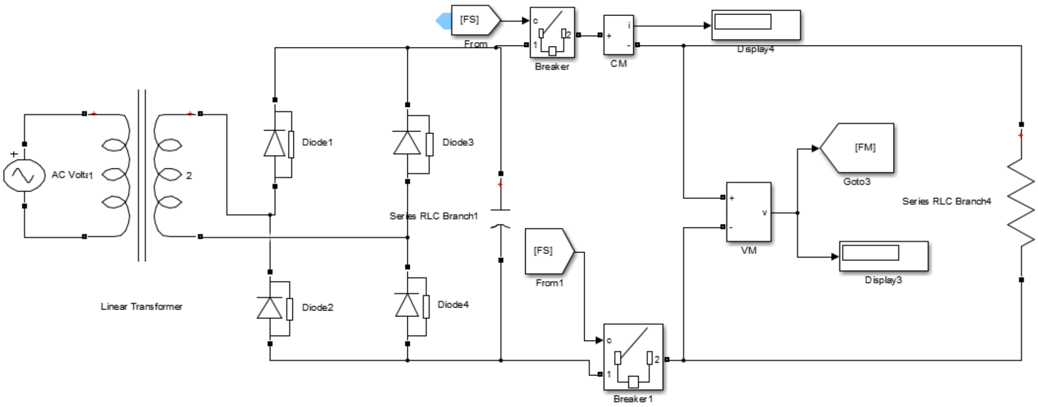

Figure 11 Grid with rectifier

The PV supply for the micro-grid and battery, in case the battery state of charge is less than 40%. the PV is working with incremental conductance MPPT control. when PV is at its maximum power production, and the PV produced power is more than demand the extra energy will be provided to the energy Stored system in this case the battery. The battery will be triggered when the PV supply is less than demand or even not available. Both cases are shown in Figures 12 (a) and (b) below. Figure 13 is the simulation of it. The calculation is shown in Appendix A.

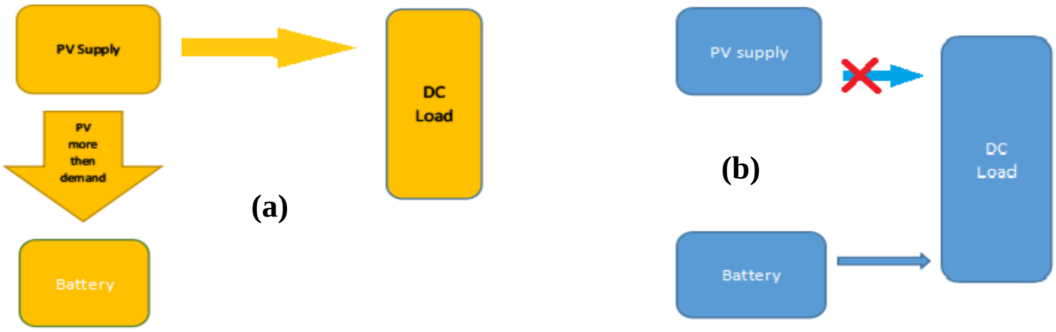

Figure 12 (a) shows PV supply to battery and load (b) shows Battery supply to the load

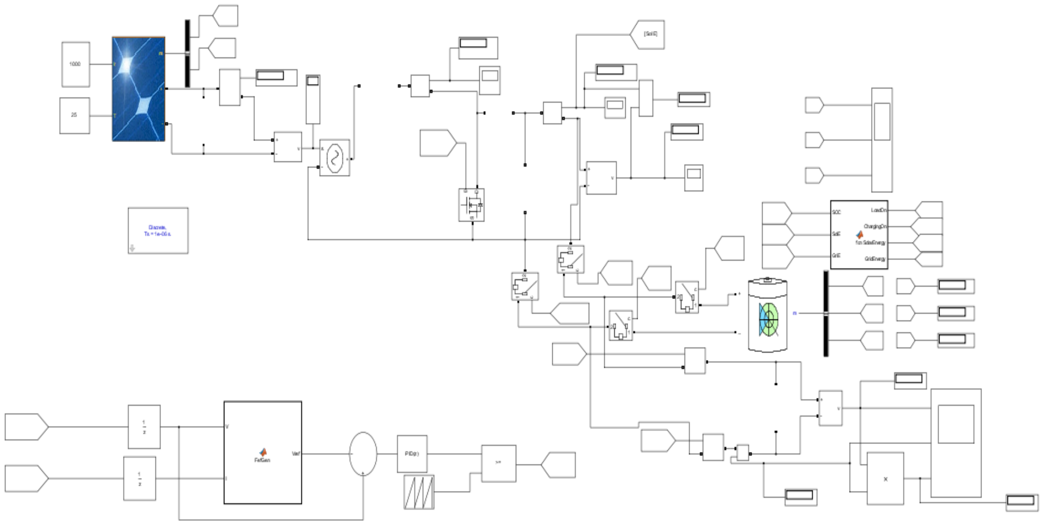

Figure 13 PV, Battery and Load simulation

B. PV with Grid simulation

The micro-grid is connected with the utility supply. When the PV supply is unavailable and the battery charge is below the recommended amount by using the programable circuit breaker. As shown in the figure following a and b figures.

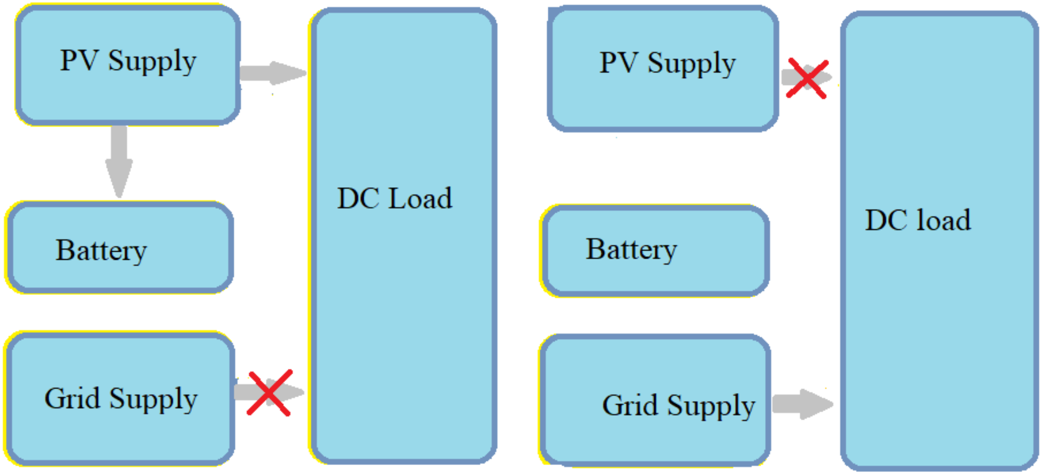

Figure 14 When PV and Battery cannot supply the load the is the supplier

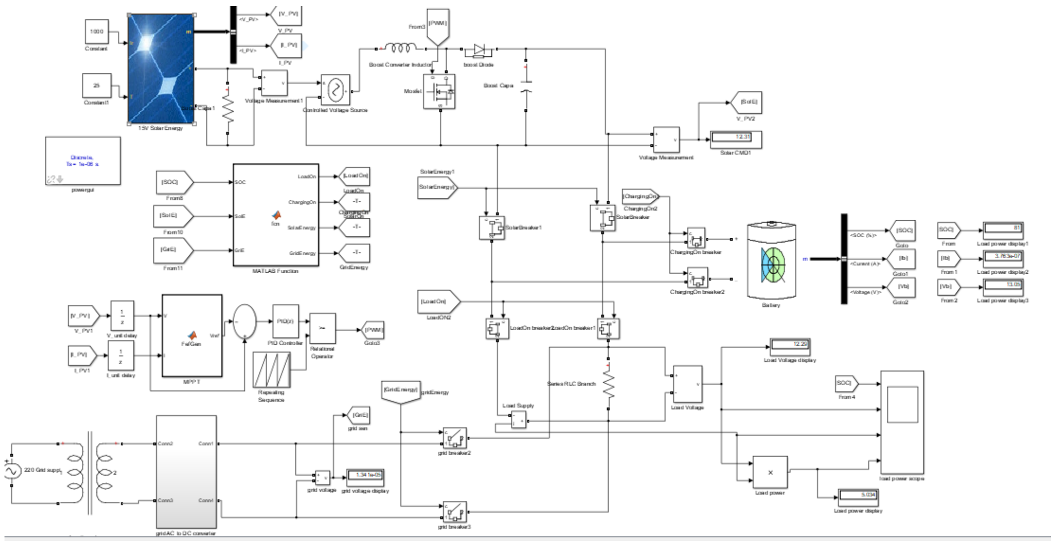

Figure 15 When PV and Battery cannot supply the load the grid is the supplier simulation

C. Different Scenarios by SIMULINK

- When PV is the supplier to the battery and load grid and Generator are disconnected.
- When grid is the supplier the objected load, PV as well as battery are disconnected.

1. Case 1 PV is the supplier to Load and Battery

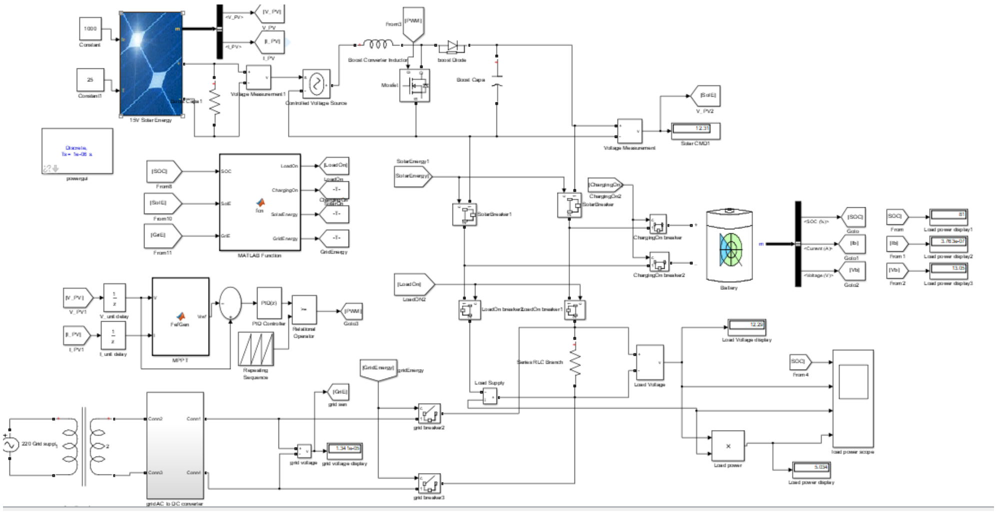

Figure 16 Case 1 PV is the supplier to Load and Battery

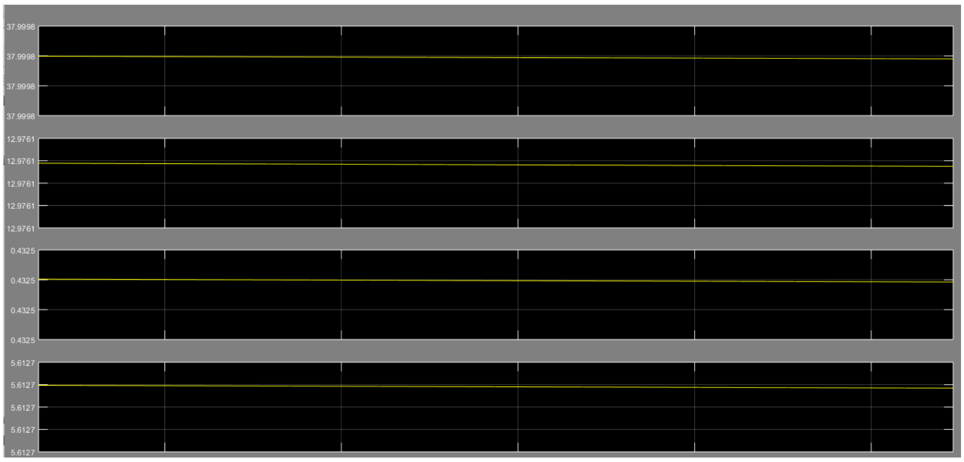

Figure 17 Case 1 PV supply Load and Battery SOC Load Voltage Load Current Load Power Respectively

2. Case 2 PV Supply Load Only

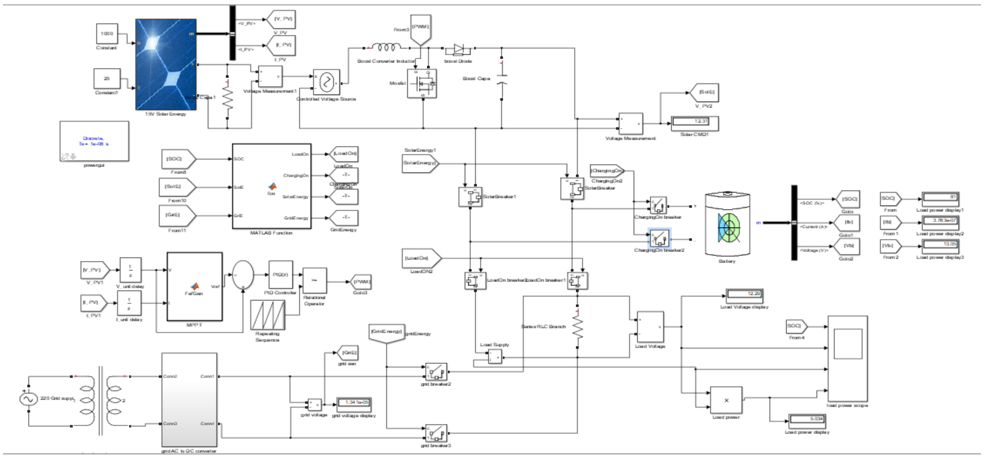

Figure 18 Case 2 PV Supply Load Only

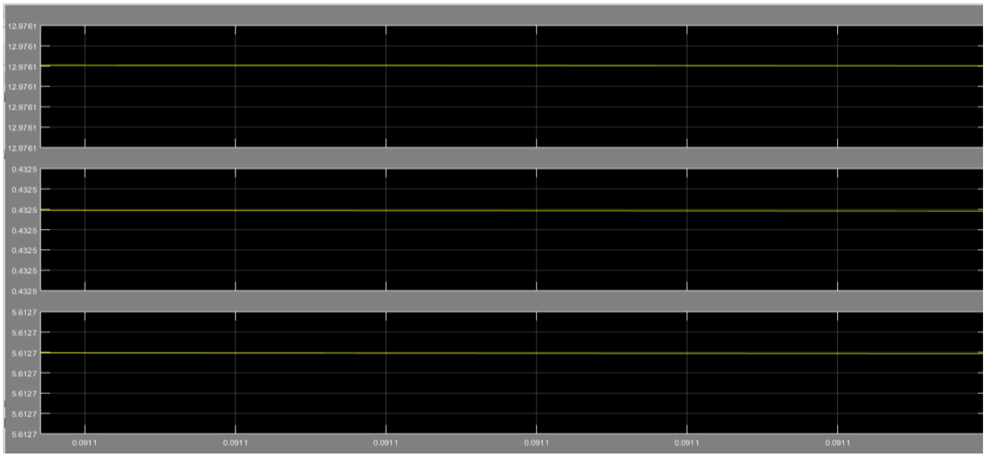

Figure 19 PV Supply Load Only Load Voltage Load Current Load Power respectively

3. Case 3 Grid Supply Load

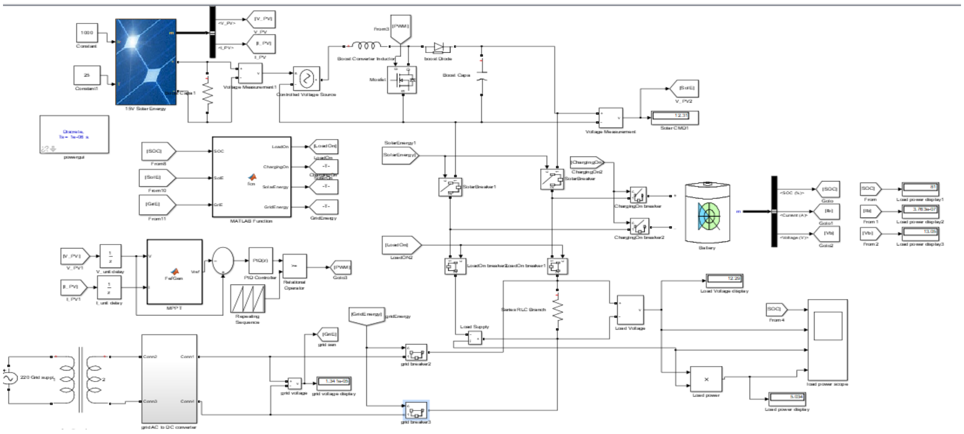

Figure 20 Case 3 Grid Supply Load

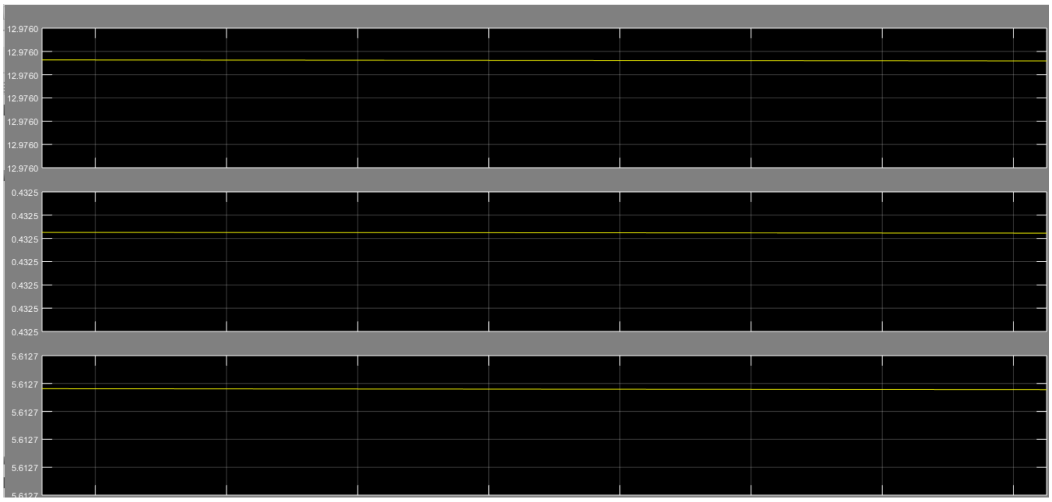

Figure 21 Grid Supply Load Voltage Load Current Load Power Respectively

4. Case 4 Battery Supply Load only

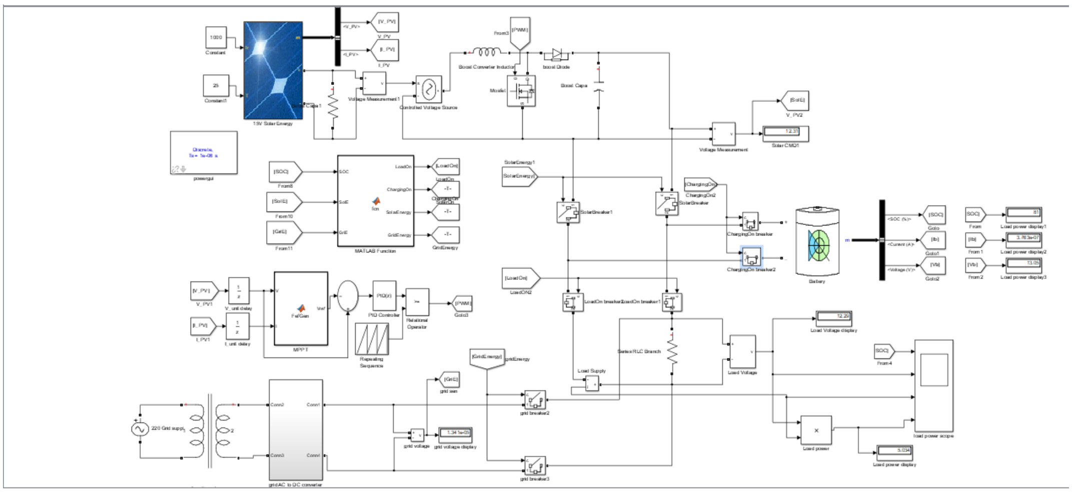

Figure 22 Case 4 Battery Supply Load only

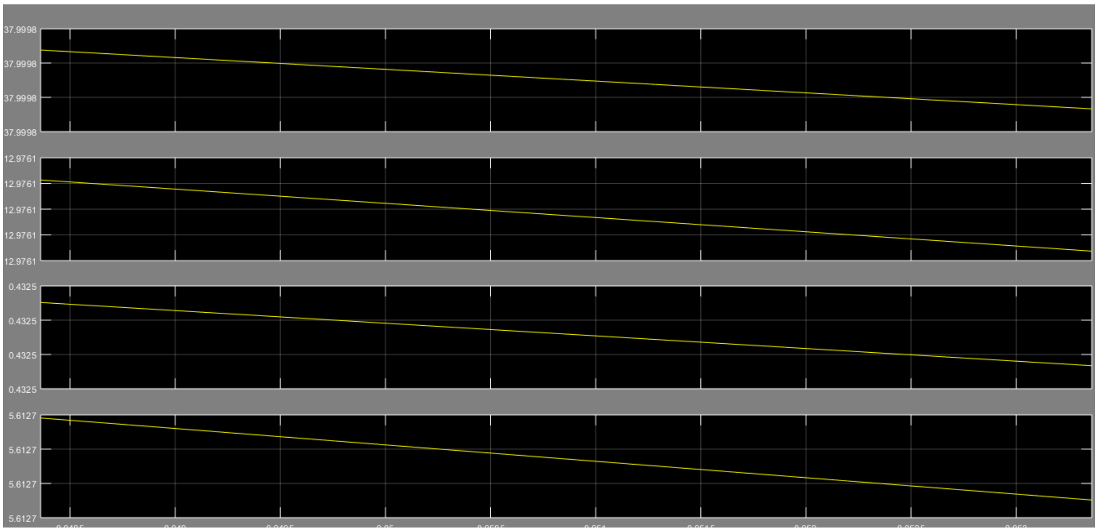

Figure 23 Case 4 Battery Supply Load Only Battery SOC Load Voltage Load Current Load Power

- *MATLAB function MPPT code for PV:*

```
function Vref = FefGen(V,I)

Vrefmax = 12;
Vrefmin = 0;
Vrefinit =0 ;
deltaVref = 1;

persistent Vold Iold Vrefold;

dataType = 'double';

if isempty (Vold)
    Vold = 0;
    Iold = 0;
    Vrefold = Vrefinit;
end

dV = V - Vold;
dI = I - Iold;

if (dV==0)
    if(dI==0)
        Vref = Vrefold;
    else
        if(dI>0)
            Vref = Vrefold + deltaVref;
        else
            Vref = Vrefold - deltaVref;
        end
    end
```

Figure 24 MPPT code

```
if (dV==0)
    if(dI==0)
        Vref = Vrefold;
    else
        if(dI>0)
            Vref = Vrefold + deltaVref;
        else
            Vref = Vrefold - deltaVref;
        end
    end
else
    if(dI/dV == (-I/V))
        Vref = Vrefold;
    else
        if(dI/dV > (-I/V))
            Vref = Vrefold + deltaVref;
        else
            Vref = Vrefold - deltaVref;
        end
    end
end

if Vref >= Vrefmax || Vref<= Vrefmin
    Vref = Vrefold;
end

Vrefold = Vref;
Vold    = V;
Iold    = I;
```

Figure 25 MPPT code

D. Circuit Breaker Control

For every circuit, I have installed two programmable switches. The switches work in following manner. The first priority is to the PV energy, it means the solar energy will feed the load and if we have extra energy the it will be stored in energy storage. At the absent of PV the load will be supplied by the battery. If the battery and PV cannot arrange the demanded power, the programable switch will change to the grid. Our last resort is generator when we have no solar energy, no battery and no grid energy. The generator will also be very beneficial in case of emergency.

```
function [LoadOn, ChargingOn, SolarEnergy,GridEnergy] = fcn(SOC,SolE,GriE)
%#codegen
LoadOn = 1;ChargingOn = 1;SolarEnergy = 1;GridEnergy = 0 ;
if(SOC>= 80) if(SolE>0) if(GriE>0)
        SolarEnergy=1;GridEnergy=0;LoadOn=1;ChargingOn=0;

        end
    end
end
if(SOC<40) if(SolE>0) if(GriE>0)
        SolarEnergy=1; GridEnergy=0; LoadOn=1;ChargingOn=1;

       end
   end
end
if(SolE<=0) if(GriE>0)
     SolarEnergy=0; GridEnergy=1;
     LoadOn=0; ChargingOn=0;
    end
end

if(SolE <= 0) if(GriE <= 0) if(SOC<40)

          SolarEnergy=0; GridEnergy=0; LoadOn =1;

        end
    end
end
```

Figure 26 Circuit Breakers Code

V. CONCLUSION

Microgrids which are part of the Smart grid system energy systems, will spread rapidly in the coming years. The main objective of this study is optimal power flow from microgrid to the load without any uncertain power injection, which allows the dispatches of solar energy to operate at an economic optimum. In order to provide high quality and uninterrupted energy, the selected sources and loads for the microgrids should be considered and power flow analysis should be done. In this study, the power flow of the simulated microgrid is obtained by MATLAB Simulink.

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APPENDICES

A.1. Calculations

A.1.1 Boost Converter

Calculation for boost converter are as follow:

$$D = 1 - \rho(\frac{V_{in}}{V_o})\rho$$

Equation 19

$$L >= D\frac{(\mathbf{1 - D^2})R}{2f}$$

Equation 20

$$C >= \frac{\mathbf{D}}{R(\frac{\Delta V_{out}}{V_{out}})f}$$

Equation 21

$$R = \frac{{V_{out}}^2}{P_{out}}$$

Equation 22

ΔV_{out} is the maximum ripple voltage.

F is the switching frequency which used (25 KHZ).

Battery will provide 12 VDC.

capacitor is 1.5 %, the result calculations will be:

D= 0.5.

L = 30.4 ×10-6 Henrry.

C = 3330 ×10-5 Farad.

A.1.1 PID controller

The proportional-integer-derivative controller is used to keep the desired output voltage, Vo. The figure shown below represents a diagrammatic represents of the proportional-integer-derivative controller. The output voltage signal is multiplied by gain value which results in the following value for Vo =1/14.7 the input signal is compared with reference value Vref.

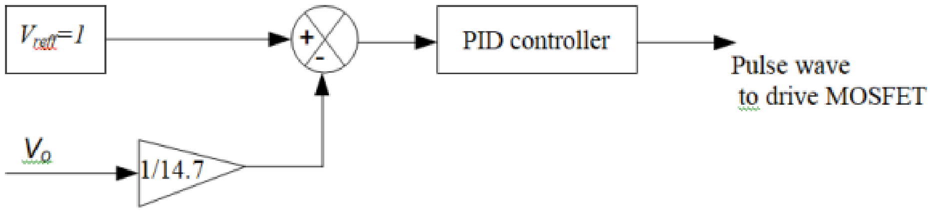

Figure 27 PID control for PV

A.2 Grid Supply

The main grid supply is reduced to 220V peak voltage. The Transformer uses RMS value, so

225~=156V RMS.

The load pure and we have to reduce the 156V RMS to bus voltage, thus we put transform's second winding as 15VRvs. Then we will change the AC to DC that is 15VdDC.

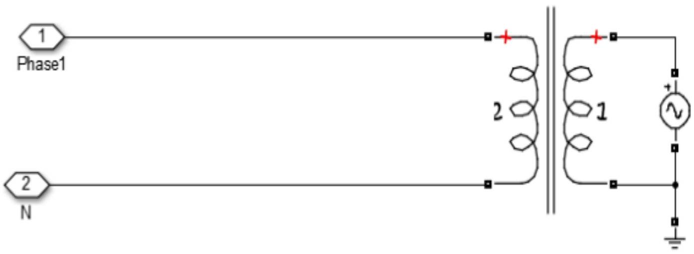

Figure 28 Transformer for Grid

A.3 Sources Connection

1) All the source must provide same voltage.

2) All source must be arranged to bus type. If the bus is dc, then all AC sources should be changed to AC and if bus is AC then all the source supply must be changed to AC energy.

3) If the bus is AC then all the sources mush has to same frequency.

ÖZGEÇMİŞ

- EDUCATION

Bachelor: 2016, Kabul Engineering University , Mechanical Engineering

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- LANGUAGES
- Pashto: Native
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- Turkish:Advance
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- Persian: Advance
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- Training of trainers (TOT)
- Pv System course (IEEE)
- ICDL (International Computer Driving)
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