B. TECH. PROJECT REPORT

On

DESIGN OF COMPONENTS IN MICROGRID

BY

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DISCIPLINE OF ELECTRICAL ENGINEERING

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DESIGN OF COMPONENTS IN MICROGRID

A PROJECT REPORT

Submitted in partial fulfillment of the
requirements for the award of the degrees

Of
BACHELOR OF TECHNOLOGY
In
ELECTRICAL ENGINEERING

Submitted by:
G.VEERENDRA

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Dr.TRAPTI JAIN

INDIAN INSTITUTE OF TECHNOLOGY INDORE
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CANDIDATE'S DECLARATION

We hereby declare that the project entitled **" Design of Components in a Microgrid"** submitted in partial fulfillment for the award of the degree of Bachelor of Technology in 'Electrical Engineering' completed under the supervision of **Dr.Trapti Jain, Asst. Professor, Dept. of Electrical Engineering,** IIT Indore is an authentic work.

Further, I/we declare that I/we have not submitted this work for the award of any other degree elsewhere.

Signature and name of the student(s) with date

Guntupalli. Veerendra

CERTIFICATE by BTP Guide(s)

It is certified that the above statement made by the students is correct to the best of my/our knowledge.

Signature of BTP Guide with dates and their designation

Dr.Trapti Jain

Assistant Professor

Preface

This report on “Design of Components of Microgrid" is prepared under the guidance of Dr.Trapti Jain .Through this report we have tried to give a detailed design of components in a microgrid. The components in a microgrid are photovoltaic (PV) array, wind turbine, and battery storage via a common dc bus. Versatile power transfer was defined as multimode of operation, including normal operation without use of battery, power dispatching, and power averaging, which enables grid- or user-friendly operation, design is technically and economically sound and feasible.

We have tried to the best of our abilities and knowledge to explain the content in a lucid manner.

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I would like to put forward my words of gratitude to my supervisor Professor Dr.Trapti Jain for experienced guidance and generous support despite busy schedules. Whenever I had doubts over some theories or I suffered from bouts of lack of self-confidence, their words of motivation helped me keep my focus and to work on.

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Last but not the least, my family and friends have been extremely supportive and understanding of my long working hours on this project. I take this opportunity to thank them for being with me always.

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Abstract

This project presents power-control strategies of a microgrid with versatile power transfer. The microgrid is the combination of photovoltaic (PV) array, wind turbine, and battery storage via a common dc bus. Versatile power transfer was defined as multimodes of operation, including normal operation without use of battery, power dispatching, and power averaging, which enables grid- or user-friendly operation. A supervisory control regulates power generation of the individual components so as to enable the microgrid to operate in the proposed modes of operation. The concept and principle of the microgrid and its control were described. A simple technique using a low-pass filter was introduced for power averaging. A modified hysteresis-control strategy was applied in the battery converter. Modeling and simulations were based on an electromagnetic-transient-analysis program. A 50-kW hybrid inverter and its control system were developed. The simulation and experimental results were presented to evaluate the dynamic performance of the hybrid system under the proposed modes of operation.

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Chapter 1
Introduction

1.1 Introduction

Recent developments in the electric utility industry are encouraging the entry of power generation and energy storage at the distribution level. Together, they are identified as distributed generation (DG) units. Several new technologies are being developed and marketed for distributed generation, with capacity ranges from a few kW to 100 MW. The DG includes micro turbines, fuel cells, photovoltaic systems, wind energy systems, diesel engines, and gas turbines.

1.1.1 Definition of Microgrid (MG)

The Microgrid (MG) concept assumes a cluster of loads and micro sources operating as a single controllable system that provides both power and heat to its local area. This concept provides a new paradigm for defining the operation of distributed generation The micro sources of special interest for MGs are small (<100-kW) units with power electronic interfaces. These sources are placed at customers sites. They are low cost, low voltage and have a high reliability with few emissions. Power electronics provide the control and flexibility required by the MG concept. A properly designed power electronics and controllers insure that the MG can meet the needs of its customers as well as the utilities defined characteristics of MGs as;

1. Not centrally planned (by the utility)
2. Not centrally dispatched.
3. Normally smaller than 50-100 MW.
4. Usually connected to the distribution system.

Implementing an MG can be as simple as installing a small electricity generator to provide backup power at an electricity consumer's site, or it can be a more complex system that is highly integrated with the electricity grid that consists of electricity generation, energy storage, and power management systems. They comprise a portfolio of technologies, both on supply side and demand-side that can be located at or near the location where the energy is used. MG devices provide opportunities for greater local control of electricity delivery and consumption. They also enable a more efficient use of waste heat in combined heat and power (CHP) applications, which boosts efficiency and lowers emissions. The CHP systems provide electricity, hot water, heat for industrial processes, space heating and cooling, refrigeration, and humidity control to improve indoor air quality and comfort.

This consists of a group of feeders. There is a single point of connection to the main distribution utility called point of common coupling (PCC). SD means a Separation Device that can disconnect MG immediately when a fault occurs in the distribution grid. Some feeders, (feeders 1, 2) have sensitive loads, which require local generation. The traditional loads are connected to Feeder 3 and do not have any local generation. Each of the local generation has a LC (local Controller). This is responsible for local control that corresponds to a conventional controller (ex. AVR or Governor) but that has a network communication function to exchange information between other LCs and the upper central controller to achieve an advanced control, The central controller also plays an important role as a central load dispatch control center in bulk power systems, which is in charge of distributed generator operations installed in MG.

MG technologies are playing an increasingly important role in the nation's energy portfolio. They can be used to meet baseload power, peaking power, backup power, remote power, power quality, and cooling and heating needs. Customers usually own small-scale, on-site power generators, but they may be owned and operated by a third party. If the distributed generator does not provide 100% of the customer's energy needs at all times, it can be used in conjunction with a distributed energy storage device or a connection with the local grid for backup power. The MG resources support and strengthen the central-station model of electricity generation, transmission, and distribution. The diagram below shows how the grid looks after the addition of distributed resources. Although the central generating plant continues to provide most of the power to the grid, the distributed resources meet the peak demands of local distribution feeder lines or major customers. Computerized control systems, typically operating over telephone lines, make it possible to operate the distributed generators as dispatch able resources that generate electricity as needed.

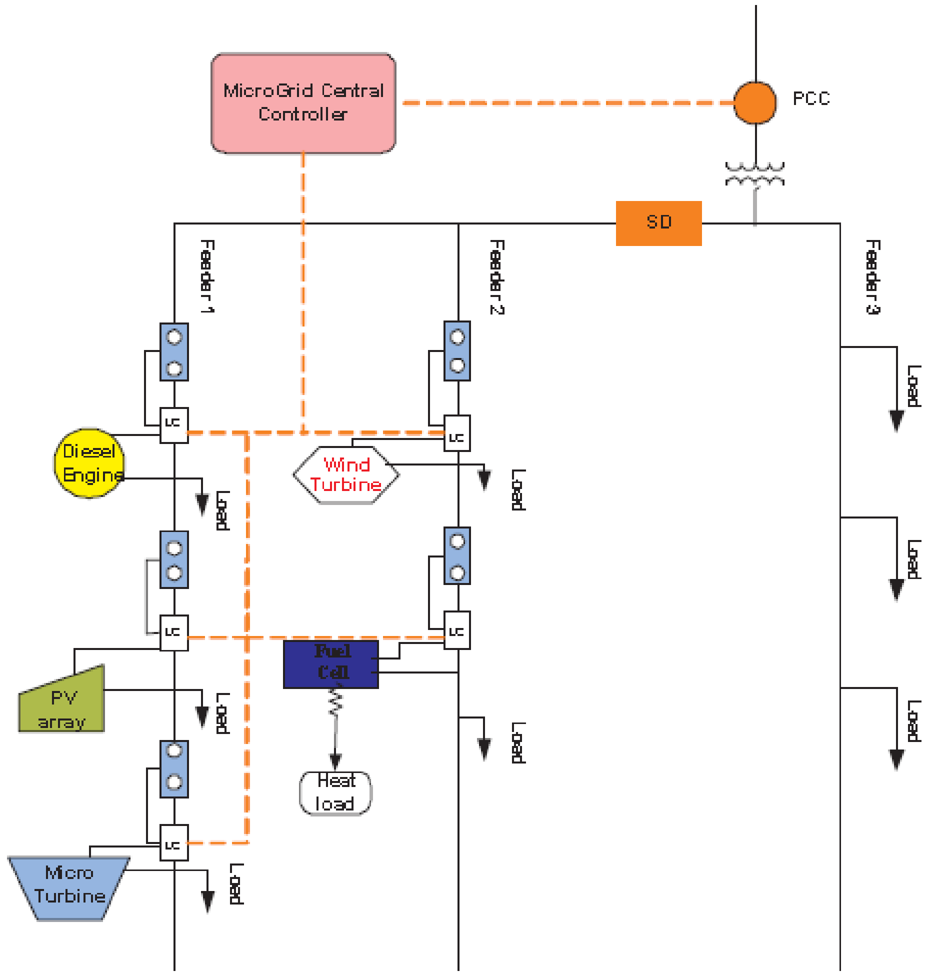

Figure1.1 Microgid Architecture

1.1.2 Reasons for Microgrids

The conventional arrangement of modern large power system offers a number of advantages. Large generating units can be made efficient and operated with only a relatively small number of personnel. The interconnected high voltage transmission network allows the generator reserve requirement to be minimized, the most efficient generating plant to be dispatched at any time, and bulk power to be transported large distances with limited electrical losses. The distribution network can be designed for unidirectional flows of power and sized to accommodate customer loads only. However, over the last few years a number of influences have combined to lead to the increased interest in MGs schemes.

The policy drivers encouraging MGs are:

1. Reduction in gaseous emissions (mainly CO2).
2. Energy efficiency or rational use of energy.
3. Deregulation or competition policy.
4. Diversification of energy sources.
5. National power requirement.
    - Availability of modular generating plants.
    - Ease of finding sites for smaller generators.
    - Short construction times and lower capital costs of smaller plants.
    - Generating may be sited closer to load, which may reduce transmission costs.
    - Technical impacts of Microgrids on the distribution system.
    - Network voltage changes and regulation.

1.2 Motivation

Currently a lot of research is being undertaken into MGs. Although the components of a MG are fairly well understood, the system as a whole is not. When several sources are connected to form a MG, the system behaviour is unpredictable. This being the case, modelling the system and simulating it in order to develop an appropriate control system, is the heart of micro-grid research. Nowadays several research groups around the world are investigating the feasibility and benefits that the MGs may provide. Some problems are encountered including dealing with unbalanced loads and harmonics associated with the system. This work does not intend to address such problems, rather it is concerned with the modelling of the MG for the investigation of the transient and steady-state response.

1.3 Technical Impacts of Microgrids on the distribution system

1.3.1 Network voltage changes and system regulation

Every distribution utility has an obligation to supply its customer's electricity at a voltage within a specified limit. This requirement often determines the design and expense of the distribution circuit so that over the years techniques have been developed to make the maximum use of distribution circuits to supply customers within the required voltage. Some distribution utilities use more sophisticated control of the on load tap changers of the distribution transformer by regulators on the feeder and including the use of the current signal compounded with the voltage measurement at the switched capacitor on feeders. Feeding power from a Distribution Generator (DG) unit can cause negative impacts on the network voltage in case a Distribution Generator (DG) unit is placed just downstream to a load tap-changer transformer. In this case, the regulators will not correctly measure the feeder demands. Rather, they will see lower values since the Distribution Generator (DG) unit reduces the observed load due to the onsite power generation. This will lead to setting the voltage at lower values than that required to maintain adequate levels at the tail ends of the feeder. However, the most favorable locations of Distribution Generator (DG) units near the end user terminals can provide the required voltage support at the feeder nodes.

1.3.2 Increase of network fault levels

Most of the MG plants use rotating machines and these will contribute to the network fault levels. Both induction and synchronous generators will increase the fault level of the distribution system although their behaviour under sustained fault conditions differs. The fault level contribution can be reduced by introducing impedance between the generator and the network by a transformer or reactor but at the expense of increased losses and wider voltage variations at the generator. In urban areas where the existing fault level approaches the rating of the switchgear, the increase in fault level can be a serious impediment to the development of Distributed Generation.

1.3.3 Power quality

Two aspects of power quality are usually considered to be important:

(i) Transient voltage variations.

(ii) Harmonic distortion of the network voltage.

The MG can cause transient voltage variations on the network if relatively large current changes during connection and disconnection of the generator are allowed. Therefore, it is necessary to limit voltage variations to restrict the light variation. Generally, load fluctuation can cause voltage variation as well as source fluctuation. MG units have the potential to cause unwanted transient voltage variations at the local power grid. Step changes in the outputs of the MG units with frequent fluctuations and the interaction between the MG and voltage controlling devices in the feeder can result in significant voltage variations. The standalone operation of MG units gives more potential for voltage variations due to load disturbances, which cause sudden current changes to the DG inverter. If the output impedance of the inverter is high enough, the changes in the current will cause significant changes in the voltage drop, and thus, the AC output voltage will fluctuate. Conversely, weak ties in the grid integration mode give a chance for transient voltage variations to take place but lower degrees than in the standalone mode. Incorrectly designed or specified MG plants, with power electronic interfaces to the network, may inject harmonic currents, which can lead to an unacceptable network voltage distortion. The type and severity of these harmonics depend on the power converter technology, the interface configuration, and mode of operation. Fortunately, most new inverters are based on Insulated Gate Bipolar Transistor (IGBT), which uses Pulse Width Modulation (PWM) to generate quasi-sine wave. Recent advances in semiconductor technology enable the use of higher frequencies for carrier wave, which result in quite pure waveforms.

1.3.4 Protection

A number of different aspects of MG protection can be identified

- Protection of the generation equipment from internal faults.
- Protection of the faulted distribution network from fault currents supplied by the MGs.
- Anti-islanding or loss-of-mains protection.
- Impact of MGs on existing distribution system protection.

1.3.5 Stability

For Distributed Generators schemes, the objective of which is to generate power from new renewable energy sources, considerations of generator transient stability tend not to be of great significance. If a fault occurs somewhere in the distribution network to depress the network voltage and the Distributed Generator trips, then all that is lost is a short period of generation. The MGs will tend to over speed and trip on their internal protection. The control scheme in the MGs will then wait for the network condition to be restored and restart automatically. In contrast, if a DG is viewed as providing support for the power system, then its transient stability becomes of considerable importance. Both voltage and/or angle stability may be significant depending on the circumstances.

Chapter 2
SYSTEM CONFIGURATION

2.1 SYSTEM CONFIGURATION

Fig. 2.1 presents the configuration of the hybrid power and its control system. The microgrid consists of a wind turbine, a PV array, battery storage, a common dc bus, power electronic converters for conditioning the power associated with the hybrid energy sources, and a grid-interface inverter. The PV system consists of a PV array and a step-up dc–dc converter for boosting the array voltage to a higher level of common dc voltage. The wind system is composed of a wind blade, a direct drive generator, and an ac–dc converter for regulating power of the wind generator. According to operation mode, battery energy-storage system (BESS) mitigates power fluctuations of the solar and wind system, or shifts the power generation to regulate the power transferred into the grid. The BESS is divided into battery storage and a buck–booster that is a bidirectional dc–dc converter for charging or discharging the battery storage. The battery converter links the battery-terminal bus and the common dc bus, whose voltage levels are mutually different, and controls the current flow between the two buses. In some previous applications battery storage was directly linked to common dc bus without using a converter. This configuration requires more battery stacks than using a dc–dc converter, and so may lower the system economy. Also, the lifetime of battery may be degraded without appropriate control of battery current and voltage. The grid-interface inverter transfers into grid dc-power generation from the wind turbine, PV array, and BESS in the form of ac power. The control system of the hybrid generation is divided into local controllers and a supervisory controller. Local controllers include a wind-turbine controller, a PV-array controller, a battery controller, and a grid-inverter controller, which are all built in a hybrid power conditioning system (PCS). The supervisory-control system is the combination of a personal computer for remote control, its system-operation software, and communication network with the local controllers. The supervisory system monitors the entire microgrid and coordinates power generation of the individual energy sources.

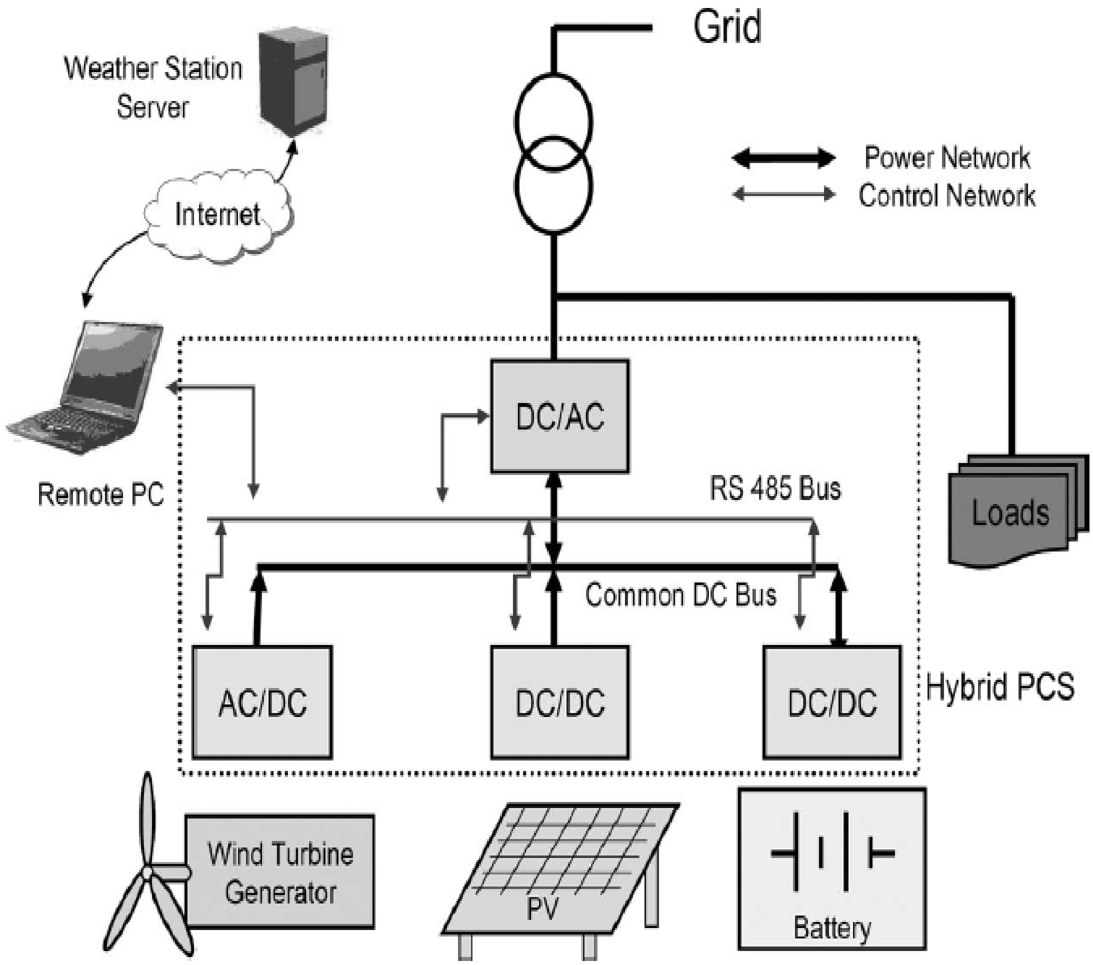

Figure. 2.1. Configuration of hybrid power and control system.

Chapter 3

CONTROL STRATEGIES

3.1 Supervisory Control

Fig. 3.1 shows the supervisory-control strategies of the grid connected system. It suggests three possible modes of operation, which are normal operation, dispatch operation, and averaging operation. A supervisory-control system monitors parameters of the local controllers and transfers control directions to them according to the mode selected by an operator. Supervisory-control strategies in three possible modes of operation are as follows.

Mode I

Normal operation: The microgrid transfers as much power into the grid as the PV array and the wind-turbine can generate. Solar irradiance and wind speed have complementary profiles and even without use of battery, better stability in power supply may be expected when compared with a single source system. It shows that a wind and solar microgrid may supply more stable power than a single wind or PV source. In normal operation, the grid inverter is directed to maintain the common bus voltage constant so that all power generation from the wind and solar sources can be delivered to the grid. For the most efficient operation, the wind turbine and PV array are controlled at all times to produce the maximum power under the given weather conditions. Battery remains off in this mode.

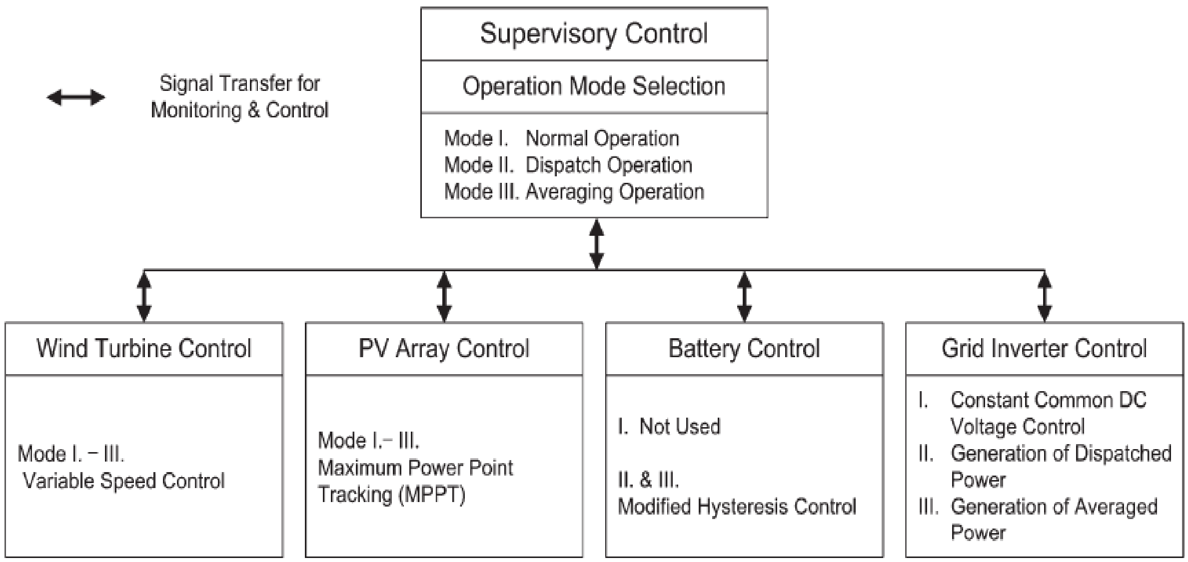

Figure. 3.1 Supervisory-control strategies of a grid-connected microgrid.

Mode II

Dispatch operation: The supervisory control sets the desired power injection to the grid. The dispatched power can be instructed for purpose of power contract with utility or demand management, such as peak-load shaving, active-load control, etc. Battery is used to compensate power mismatch between generation of PV array and wind turbine and the dispatched amount. Power fluctuations are unavoidable in wind and solar system, and power dispatch command can be continually changed by the system operator. In dispatch mode, thus, battery will experience frequent shifts in charging and discharging states. Therefore, without appropriate charging control, life expectancy of battery storage may be degraded. In this paper, a modified hysteresis-control strategy is implemented in the battery charger/discharger to reduce charging frequency and current.

Mode III

Averaging operation: The purpose of this mode is to smooth the power fluctuation of the renewable energy sources and transfer more stable power into the grid. This improves the quality of power delivered to the grid. This mode of operation mitigates the voltage and harmonic variation at the point of common coupling (PCC) with the grid. The supervisory system should include an additional control block for power averaging, and instruct the resulting averaged value for power command of the grid inverter. Averaging unpredictable power in real-time may be a complicated issue, which requires further and comprehensive study on weather forecasting and power estimation as well as a control technique itself. In this paper, a simple technique using a low-pass filter was introduced. This technique is simple but effective in mitigating power fluctuation. Use of battery is necessary for balancing the power production and injection, and its control is the same as that in mode II. The wind and PV systems are still under the maximum power control.

3.2 Local Control of the Hybrid PCS

Fig. 3.2 shows the configuration of the hybrid PCS and its local controllers. The wind controller consists of a wind-turbine speed controller and a $d-q$-frame-based current controller. The upper level controller regulates the active and reactive power, PW and QW, of the wind generator, and outputs the d- and q-axis current commands $i*w\_dq$ at which the lower level current controller regulates the wind-generator current. Three phase ac-current controller based on feedback linearization has been employed because of easy settings of gains, relatively excellent control performance, and robustness in parameter variations of the controlled system. The PV converter regulates the array voltage VPV at the reference voltage $V*PV$ commanded by the maximum power point tracking (MPPT) controller and boosts it to the level of common dc voltage. Error between the ordered and real voltage is processed through the voltage controller into the ordered current $i*PV$, which is compared with the array current i_PV. A dc–dc converter for BESS should be capable of controlling the battery current iBESS in both directions. In a battery-charging mode, the current flows from the dc bus to the battery, and in a discharging mode, the current flows in the opposite direction. Therefore, the BESS converter should be a type of a buck–booster, which may operate in buck mode for battery charging and in boost mode for battery discharging. In buck mode, the series switch ($S1$) turns activated and the parallel switch ($S2$) deactivated, and in boost mode, $S1$ turns activated and $S2$ deactivated. The BESS-mode controller determines whether to charge or discharge battery storage and outputs the common dc voltage command $V*dc$. The voltage command is compared with the actual voltage Vdc and processed into the reference current $i*$BESS that is regulated by the current controller. A grid-interface inverter injects the power from the individual source components into the grid. A control structure of the grid-side inverter is basically identical to that of the wind converter except for an upper level controller. The grid-operation controller regulates power injection into the grid according to operation modes of the microgrid.

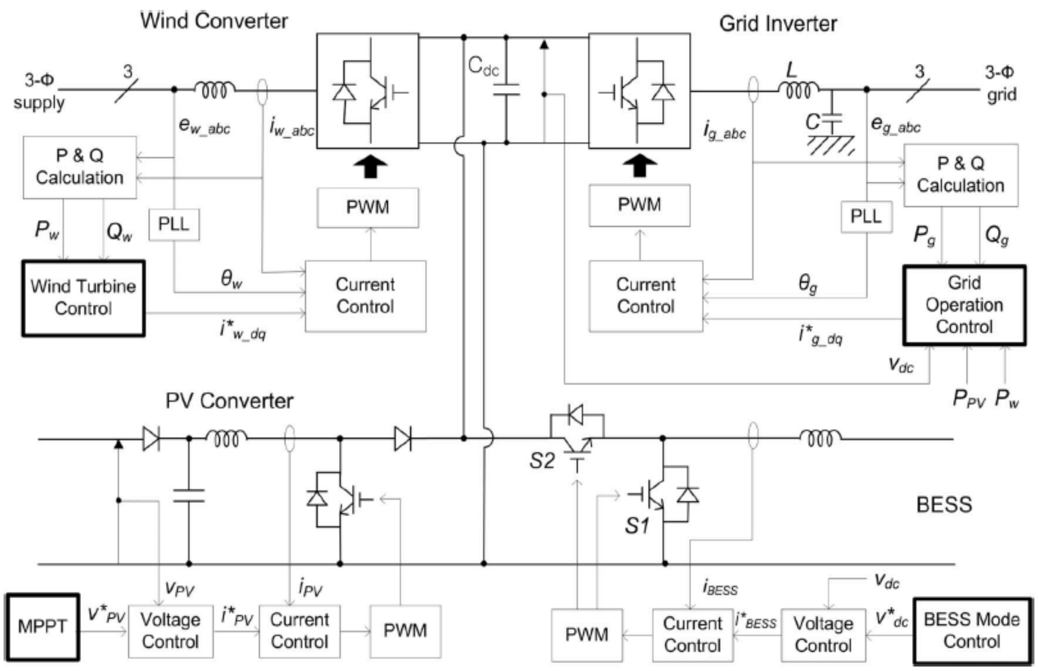

Figure.3.2. Configuration of the hybrid PCS and its local control schematic.

3.3 Wind-Turbine Control

Basic concept of wind-turbine control is to obtain the maximum power from varying wind speed and minimize the rating of the wind converter by regulating reactive power generation at zero. Below rated wind speeds, real power from the wind generator is regulated to capture the maximum energy from varying wind speed. The following equation specifies the available maximum power.

$$P_M^{\mathrm{MAX}} = \frac{1}{2}\pi\rho R^5 \frac{C_P^{\mathrm{MAX}}}{\lambda_{\mathrm{OPT}}^3}\omega_M^3$$

Where ρ is the air density, R is the blade radius, ωM is the angular speed of the wind turbine, CP_MAX is the maximum power coefficient, and λOPT is the optimal tip speed ratio. Above rated wind speeds, the maximum power control is overridden by stall regulation for constant power. Fig. 3.3 shows the power controller of the wind-side converter; the wind-turbine control block is shown in Fig. 2.2.3, which outputs the q- and d-axis current commands $i*\ w\_q$ and $i*\ w\_d$ through PI controllers.

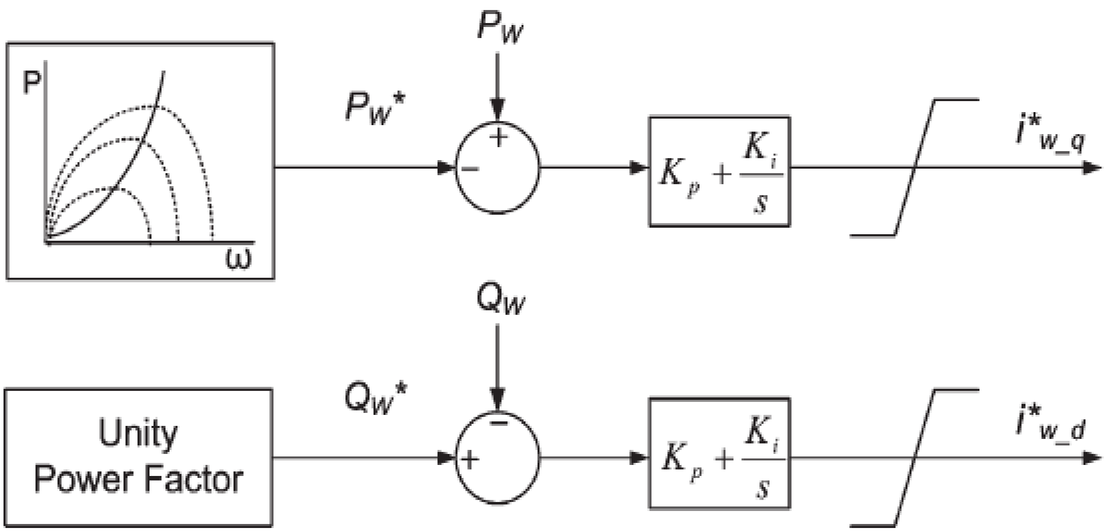

Figure. 3.3 Power controller of the wind system.

3.4 PV-Array Control

Power output of a PV array depends on the voltage level where it operates under a given condition of irradiance and cell-surface temperature. For efficient operation, a PV array should operate near at the peak point of the $V - P$ curve. Various MPPT techniques have been proposed. The incremental conductance (IncCond) method was implemented in this project. The MPPT block in Fig. 3.4 senses the PVarray current iPV and array voltage VPV and returns the array voltage command.

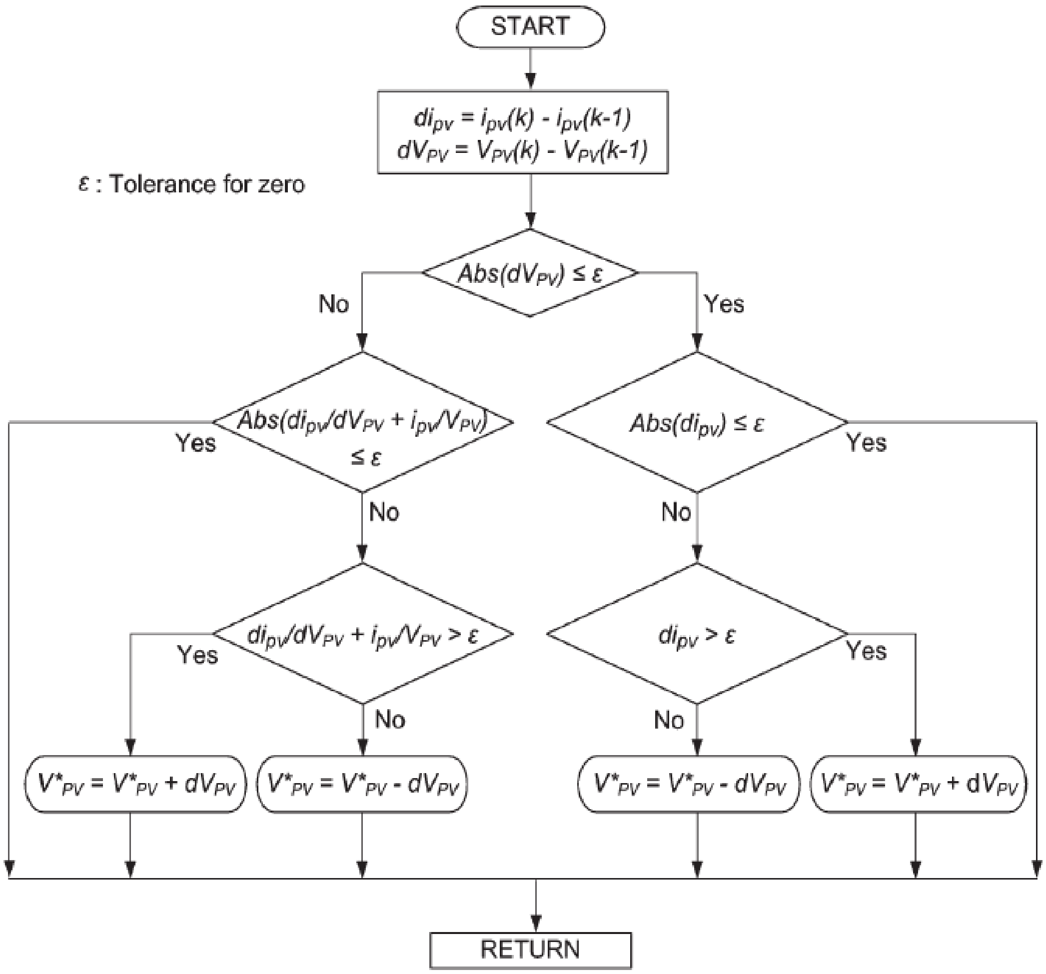

Figure. 3.4 MPPT control block (IncCond method).

3.5 Battery Control

The primary goal of the battery converter is to regulate the common dc-bus voltage. The battery load current rapidly changes according to changes in weather conditions and power command for grid inverter in dispatching or averaging mode of operation. Common dc-bus voltage must be regulated to stay within a stable region regardless of the battery-current variation. To do this, a modified hysteresis-control strategy is applied. The concept of this strategy is to regulate the common dc voltage within a specific band, for example, a hysteresis band. Therefore, the battery charger/discharger is controlled in such a way that the dc-bus voltage should not violate the specified upper and lower limits, *Vdc*_up and *Vdc*_lw, as shown in Fig. 3.5. A decision criterion for charging/discharging becomes the level of the common dc-bus voltage, and the battery buck–booster operates according to the scheme as below:

If Vdc > Vdc_up, then charging → V∗ dc = Vdc_up

If Vdc < Vdc_lw, then discharging → V∗ dc = Vdc_lw

If Vdc_lw ≤ Vdc ≤ Vdc_up, then no control (rest).

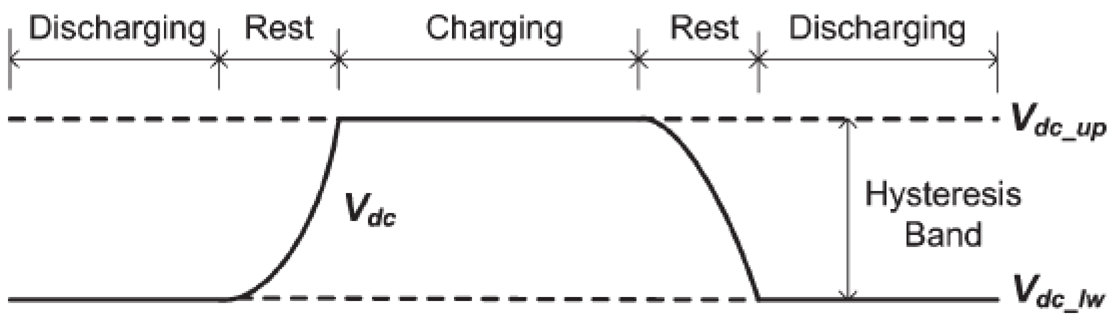

Figure. 3.5. Modified hysteresis-control strategy.

When the common dc voltage *Vdc* becomes larger than the upper limit, charging mode begins with the voltage command *V ∗ dc* equal to the upper limit and continues until the dc voltage reaches the limit. If *Vdc* goes below the lower limit, then the voltage target is bound at the lower limit and the converter starts operating in boost mode. Accordingly, the battery-mode control block in Fig. 3.2 can be built as shown in Fig. 3.5_1. There is another reason for such hysteresis control other than voltage regulation of the dc bus. It is intended to protect the battery storage against excessive charging frequency and current variation. Not by bounding dc-bus voltage at a constant value but by allowing a hysteresis band; the battery can take a rest during the rest interval in Fig. 3.5. Energy that can be extracted or stored across the hysteresis band in a dc-bus capacitor ΔEC is described as follows:

$$\Delta E_C = \frac{1}{2} C_{dc} \left(V_{dc\_\mathrm{up}}^2 - V_{dc\_\mathrm{lw}}^2 \right).$$

This energy gap is utilized for balancing PV, wind, and grid injection without use of the battery. C_dc is the capacitance of the common dc bus.

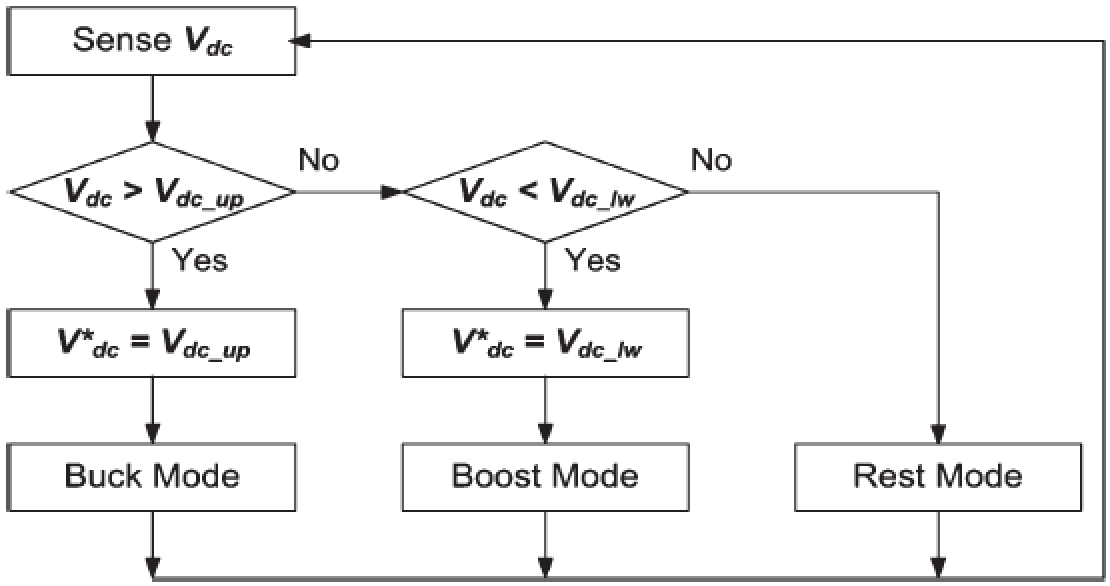

Fig. 3.5_1. Battery-mode control block (modified hysteresis).

3.6 Grid-Inverter Control

A power controller of the grid inverter in Fig. 3.2 may be constructed in three different types according to the operation modes of the microgrid.

Mode I—normal operation: The common dc-bus voltage is regulated at a constant value so that real power generation from the wind turbine and PV array can pass into the grid. Fig. 3.6 shows the voltage controller in the normal mode for power regulation.

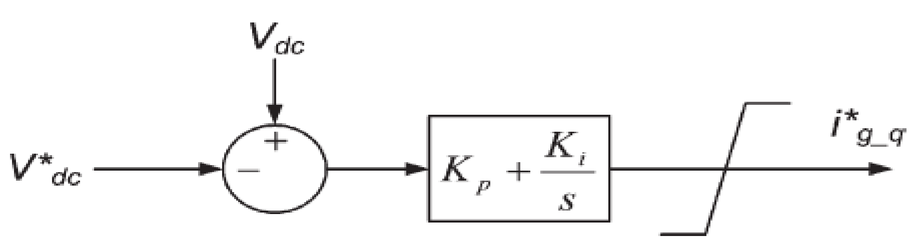

Figure. 3.6. Power controller for normal operation.

Mode II—dispatch operation: The power controller regulates the real power injection into the network *Pg* at the dispatched target *P∗g* by a user or an operator, which can be presented in Fig. 3.6_1.

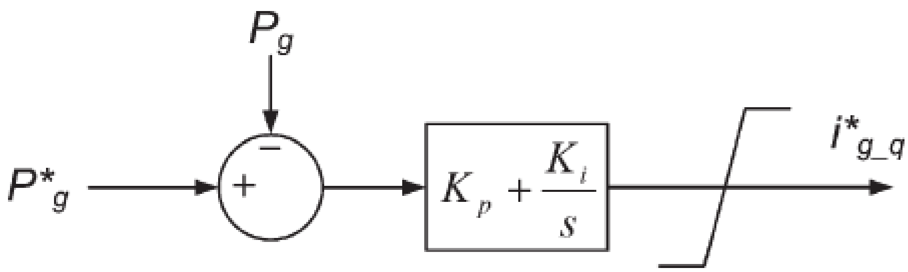

Figure. 3.6_1. Power controller for dispatch operation.

Mode III—averaging operation: A sum of the power measured from the wind and solar sources is averaged by a low-pass filter, and then, the filtered value is specified as the real power command. Averaging effect can be adjusted by setting different time constants for a low pass filter. Fig. 3.6_2 presents the power controller for averaging mode.

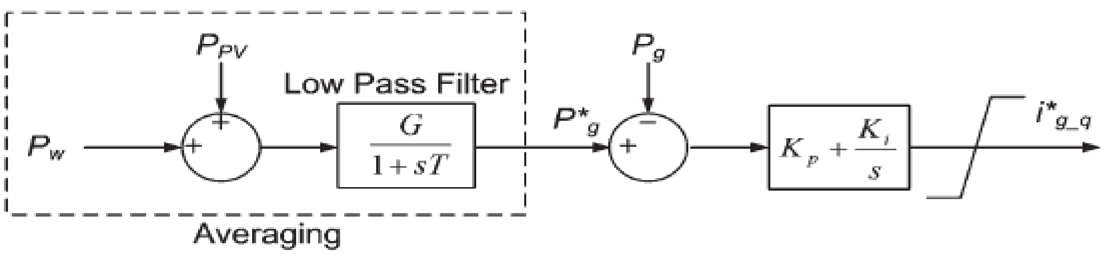

Figure. 3.6_2. Power controller for averaging operation.

Chapter 4

RESULTS AND DISCUSSION

From the previous chapters we can say that results will be of two types namely:

1. Without Energy Storage System
2. With Energy Storage System

4.1 Without Energy Storage System

1) MG without ESS under constant load (10kw) with disturbance (10kw) at 1-interval (4-5 sec).

Power diagram

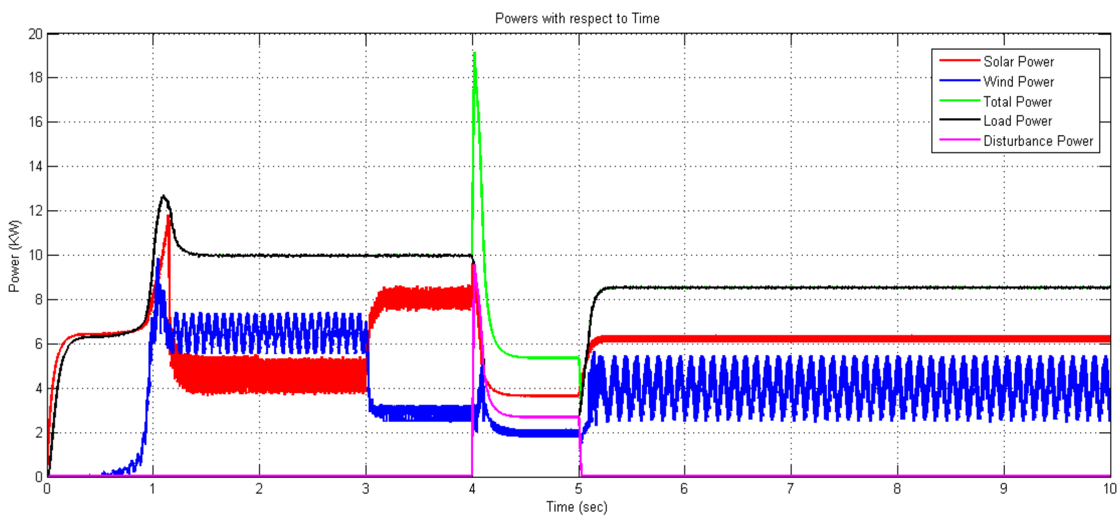

Figure 4.1

As u can see above there is no energy storage system between 4 to 5 seconds so there isn't sufficient storage so it cannot produce desire output power.

Load current diagram

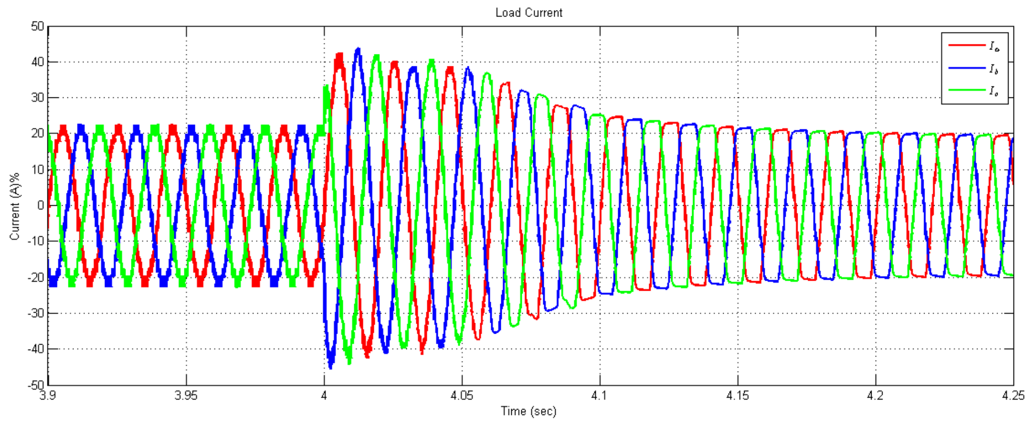

Figure 4.2

The above figure shows three phase current of load and we can see the didturbance between 4 to 5 seaconds.

2) MG without ESS at constant load (10kw) with disturbance (10Kw) at 2-interval (4-5sec and 7-8 sec).

Power diagram

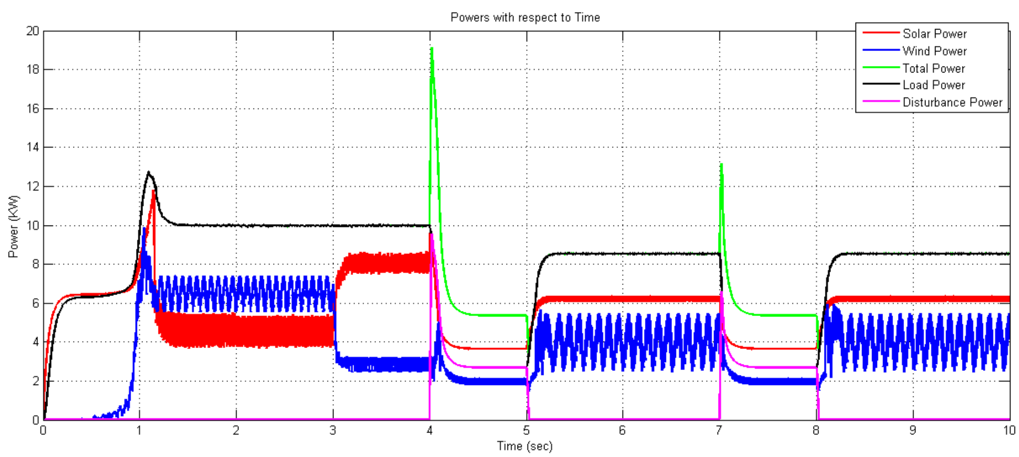

Figure 4.3

As u can see same has happened as previous case but at 2 intervals.

Load current diagram

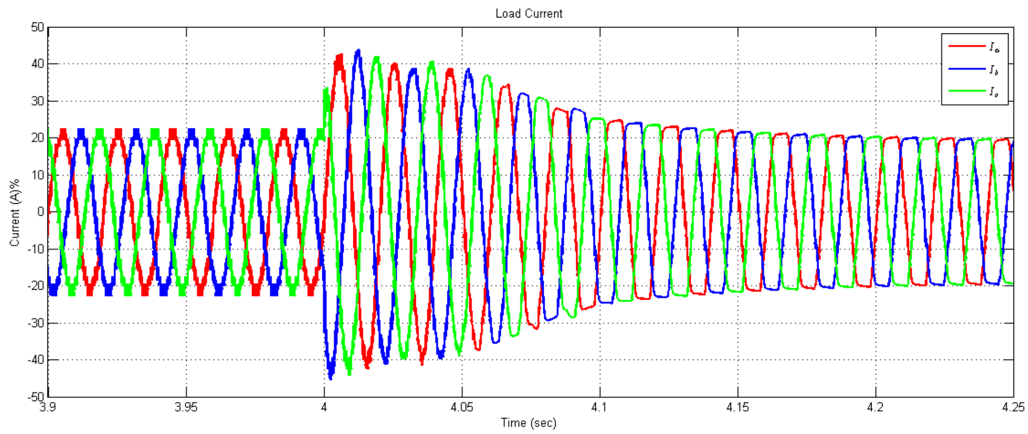

Figure 4.4 (load is applied at 4-5 sec)

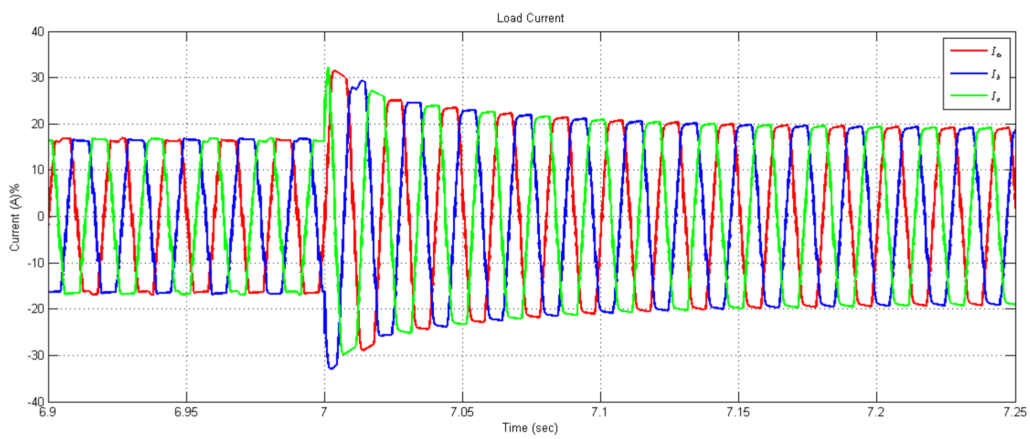

Fig 4.4_1 (load is applied at 7-8 sec)

4.2With Energy Storage System

1) MG with Energy Storage System under no load

Power diagram

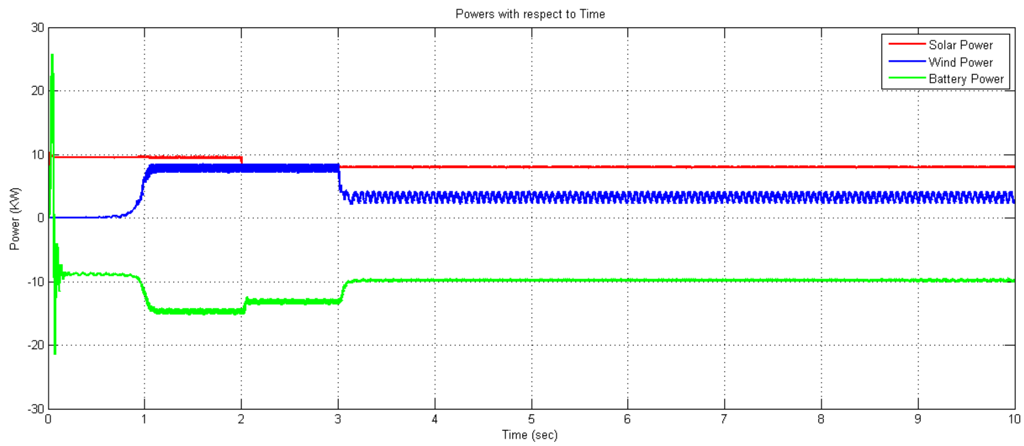

Figure 4.5

Load current diagram

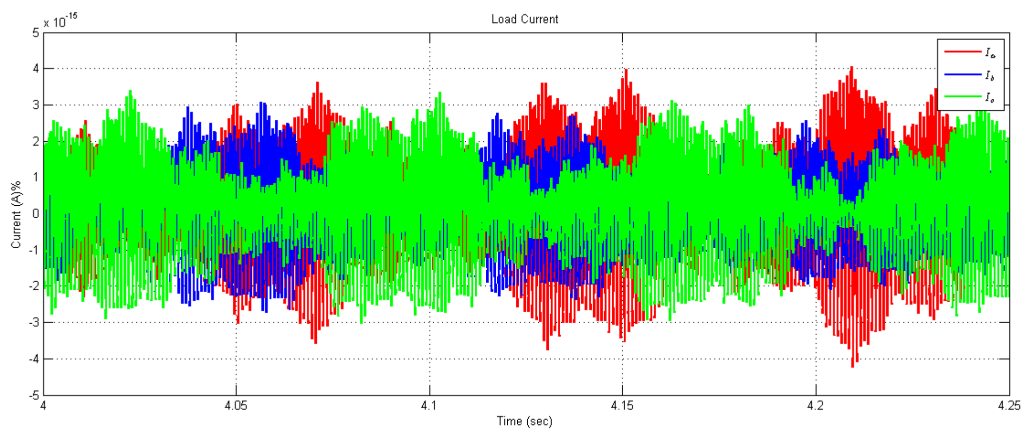

Figure 4.6

As u can observe load current is zero as there is no load.

State of Charge (SOC)

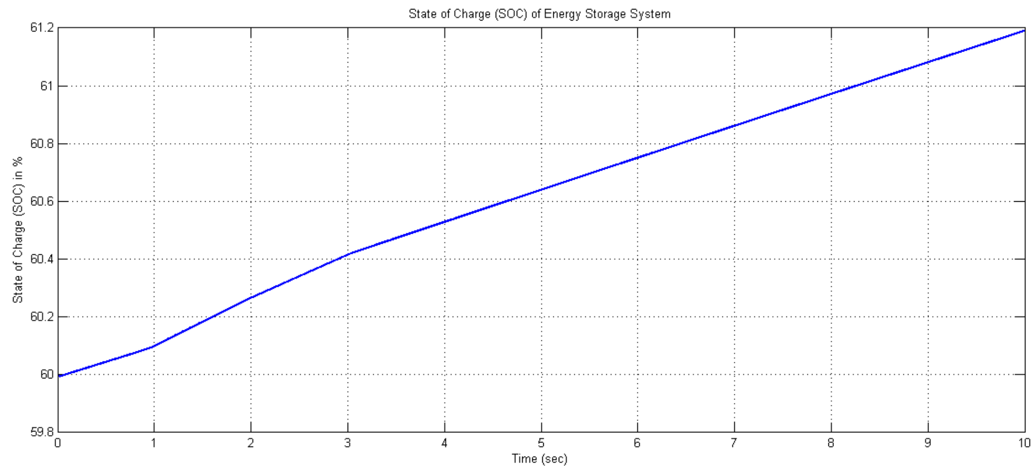

Figure 4.7

As u can observe ESS is in charging condition.

2) MG With Energy Storage System under Constant load(10kw)

Power diagram

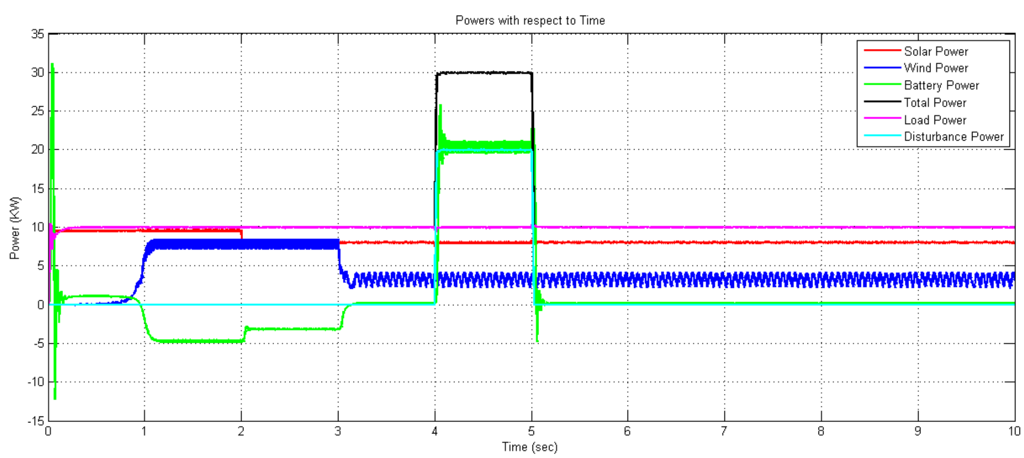

Figure 4.8

We can observe that as ESS is present it can compensate with load required.

Load current diagram

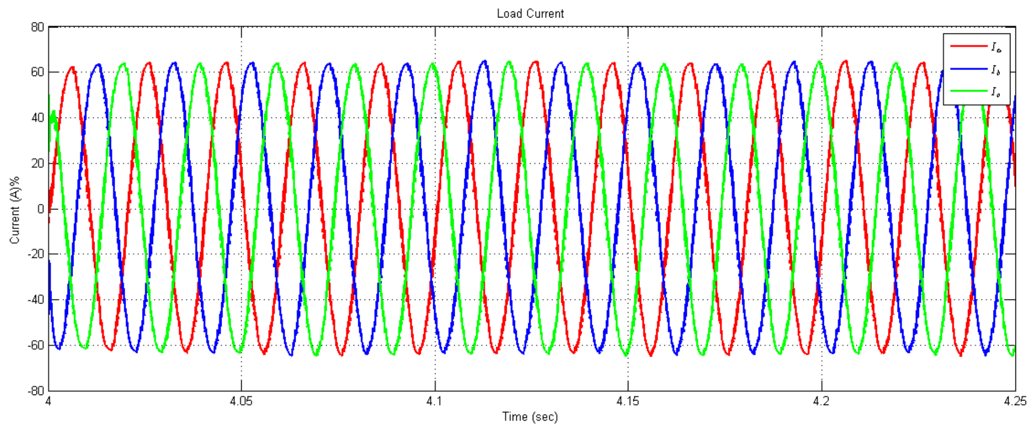

Figure 4.9

State of Charge (SOC)

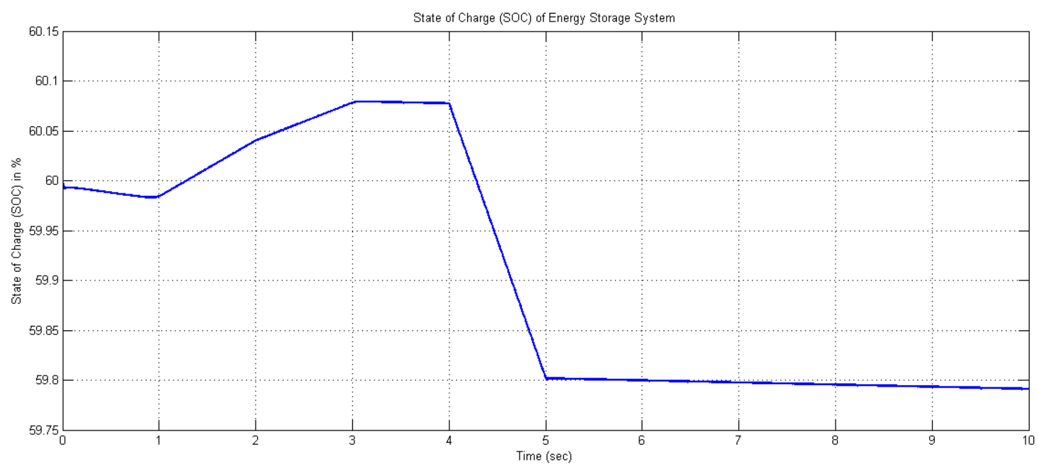

Figure 4.10

As we can see during load interval (4-5 sec) battery dissipates its power to compensate for load.

3) MG with Energy Storage System under constant load (10kw) with disturbance (20kw) at two intervals (4-5 sec) and (7-8 sec).

Power diagram

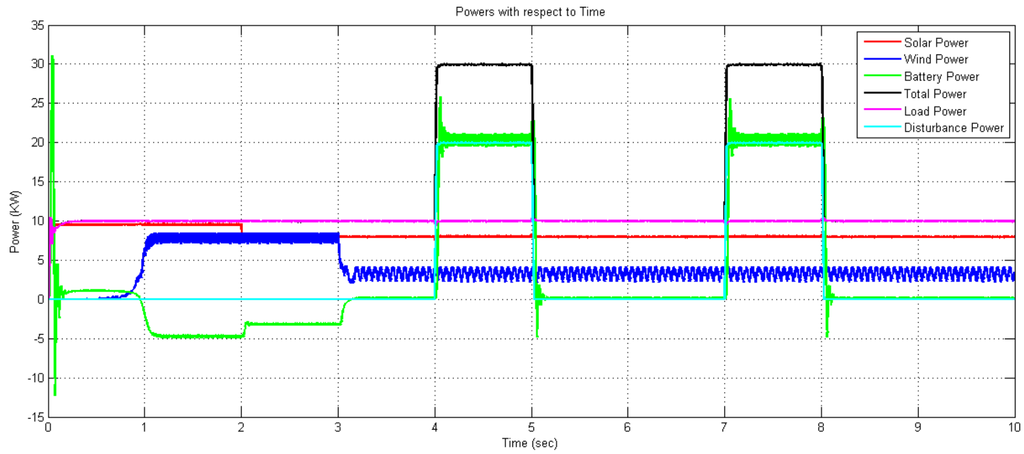

Figure 4.11

We can observe that load is applied at 2 intervals as ESS is present battery is compensating with load

Load current diagram

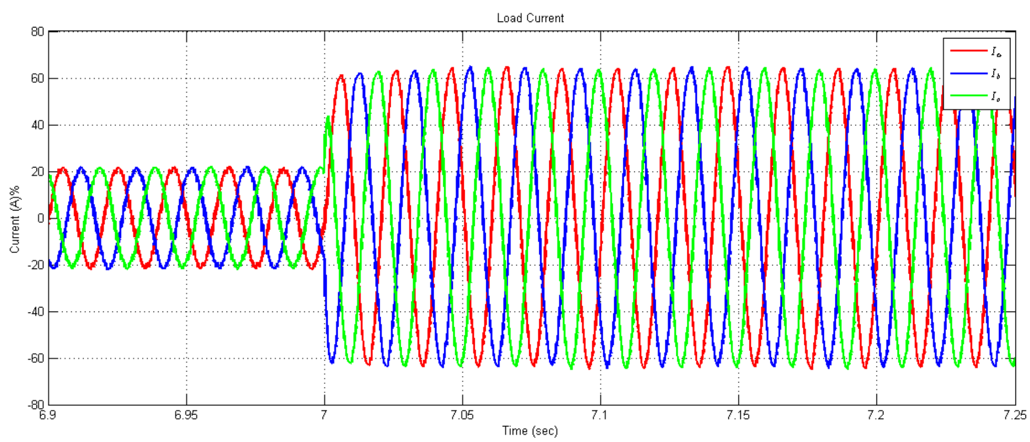

Figure 4.12(load is applied at 4-5 sec)

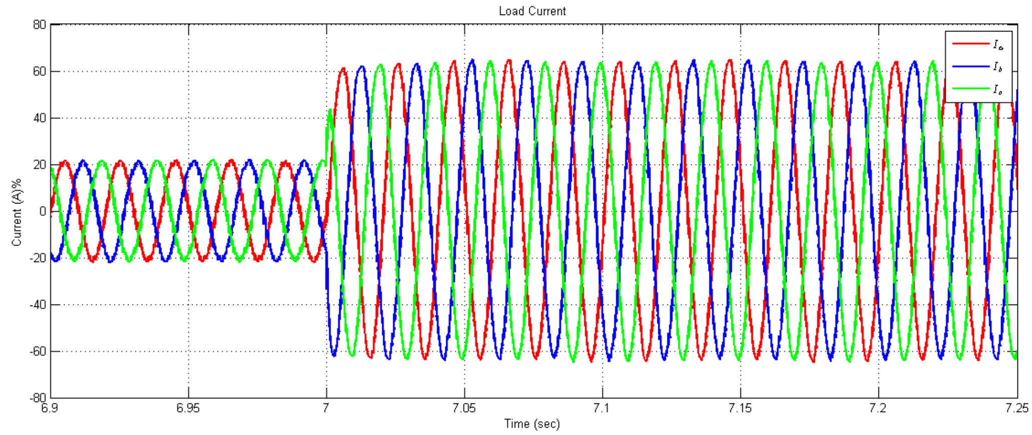

Figure 4.12_1 (load is applied at 7-8 sec)

State of Charge (SOC)

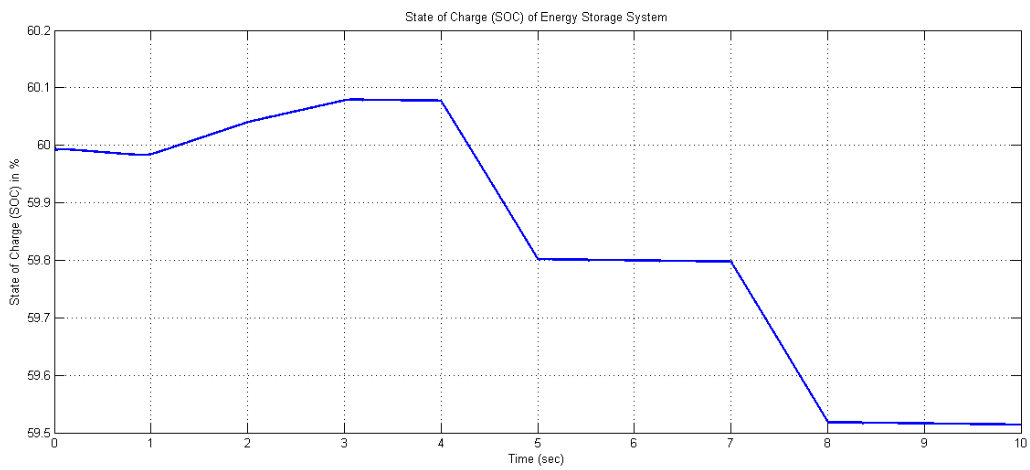

Figure 4.13

We can observe that battery is charging when there is no load and discharging when load is present

Chapter 5

CONCLUSION

1) The supervisory control successfully coordinated the individual components of the microgrid to operate in a dynamically stable way under the proposed modes of operation for versatile power transfer.1
2) The individual sources, wind turbine and PV array, could generate the maximum power regardless of not only behaviors of the grid inverter or battery but also operation modes of the microgrid.
3) The hysteresis control of the battery enabled the microgrid to efficiently operate, particularly in terms of dynamic behavior, in the proposed modes of operation under varying weather conditions.
4) Components such as PV system, Wind Turbine systems, Energy Storage System, DC/DC, DC/AC, AC/DC Converters are designed in MATLAB Simulink.
5) When Energy Storage System is not present, MG cannot be able to supply power i.e. equivalent to load disturbance.
6) When Energy Storage System is present, MG is able to compensate to load disturbance
7) Energy storage system can be able to store the power when there is surplus power generation in the MG. Further, it can also supply power when there is a sudden load disturbance.

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APPENDIX

Parameters used in the simulation study are as follows.

PV DG

a) Converter type: boost dc–dc converter.

b) Switching device and frequency: IGBT, 10 kHz.

c) Power rating: 10 kW.

d) Input PV-voltage range: 200–400 V (dc).

e) Output voltage range: 400–700 V (dc).

f) Control: MPPT (Incremental Conductance Method).

WT DG

a) Converter type: three-phase space vector pulse width modulation (svpwm) converter.

b) Switching device and frequency: igbt, 10 kHz.

c) Power rating: 20 kva.

d) Input-voltage range: ∼400 v (ac).

e) Input-frequency range: ∼120 Hz.

f) Output-voltage range: ∼700 v (dc).

g) Control: mppt, variable voltage variable frequency, scalar.

BESS

a) Converter type: step-up/down dc–dc converter.

b) Switching device and frequency: IGBT, 10 kHz.

c) Power rating: 20 kW.

d) Battery-side voltage range: 300–400 V (dc).

e) DC-bus-side voltage range: 450–700 V (dc).

f) Charging control: bulk/absorption/float.

Grid Inverter

a) Converter type: three-phase SVPWM inverter.

b) Switching device and frequency: IGBT, 10 kHz.

c) Power rating: 50 kW.

d) Rated-output voltage: 400 V LL (ac).

e) Input-voltage range: 450–700 V (dc).

f) Control: $d-q$-based current control.