DESIGN AND OPTIMIZATION OF HYBRID CONCENTRATING SOLAR AND WIND POWER PLANT FOR ENERGY AUTONOMY OF ISLANDS

PROJECT REPORT

PHASE II

Submitted by

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Register No: 15MAE003

in partial fulfilment for the requirement of award of the degree

of

MASTER OF ENGINEERING

in

APPLIED ELECTRONICS

Department of Electronics and Communication Engineering

KUMARAGURU COLLEGE OF TECHNOLOGY

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APRIL 2017

BONAFIDE CERTIFICATE

Certified that this report titled **"DESIGN AND OPTIMIZATION OF HYBRID CONCENTRATING SOLAR AND WIND POWER PLANT FOR ENERGY AUTONOMY OF ISLANDS"** is the bonafide work of **DHIVYA B [15MAE003]** who carried out the project under my supervision. Certified further, that to the best of my knowledge the work reported here in does not form part of any another project or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other student.

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ACKNOWLEDGEMENT

I express my profound gratitude to our management for giving this opportunity to pursue this course.

I express my sincere thanks to the management of Kumaraguru College of Technology and Joint Correspondent **Shri Shankar Vanavarayar** for his kind support and for providing necessary facilities to carry out the work.

At this pleasing moment of having successfully completed the project work, I wish to acknowledge my sincere gratitude and heartfelt thanks to our beloved principal **Dr.R.S.Kumar M.E., Ph.D.,** for having given me the adequate support and opportunity for completing this project work successfully.

I express my sincere thanks to **Prof.K. Ramprakash M.E.,** the ever active, Head of the PG Programmes, Department of Electronics and Communication Engineering, who rendering us all the time by helps throughout this project.

In particular, I wish to thank and everlasting gratitude to the project coordinator **Ms.S.Nagarathinam, M.E., (Ph.D).,** Associate Professor, Department of Electronics and Communication Engineering for her expert counselling and guidance to make this project to a great deal of success. With her careful supervision and ensured me in the attaining perfection of work.

I extend my heartfelt thanks to my project guide **Dr.K.Malarvizhi M.E., Ph.D.,** Head Of the Department, for her ideas and suggestions, which have been very helpful for the completion of this project work.

Last, but not the least, I would like to express my gratitude to my family members, friends and to all the staff members of Electronics and Communication Engineering Department for their encouragement and support throughout the course of this project.

ABSTRACT

Renewable energy sources can offer isolated communities the opportunity to regulate their energy use in a manner that best suits their needs. This paper presents the simulation and thermodynamic evaluation of a stand-alone hybrid power plant exclusively using renewable energy sources and storage technologies. The proposed system includes Vienna rectifier in the wind system in order to reduce voltage stress on semi conductor devices and switching losses. The analysis shows that the evaluated hybrid concentrating solar-wind power plant is a reliable alternative for satisfying the fluctuating electricity demand. In the proposed system, the system efficiency is analyzed by comparing ABC algorithm and Cuckoo Optimization Algorithm (COA). The stable output and controlled autonomous performance using the complementary character of solar and wind energy, combined with energy storage is verified by simulating using MATLAB Simulink.

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LIST OF ABBREVIATIONS

CSP	-	Concentrated Solar Power
WT	-	Wind Turbine
G/C	-	Gear system / Coupling
PM	-	Permanent Magnet
CSCFS	-	Constant Speed Constant Frequency Scheme
DSCFS	-	Dual Speed Constant Frequency Scheme
VSCFS	-	Variable Speed Constant Frequency Scheme
VSVF with DO	-	Variable Speed Variable Frequency Scheme with Double Output
HPP	-	Hydroelectric power plant
WPP	-	Wind Power Plant
Pg	-	Generated Power
Pd	-	Power Demand
PM	-	Pumping Motor
PWM	-	Pulse Width Modulation
IGBT	-	Insulated Gate Bipolar Transistors
MW	-	Mega Watt
DC	-	Direct Current
AC	-	Alternating Current
MOSFET	-	Metal Oxide Semiconductor Field

		Effect Transistors
VSI	-	Voltage Source Inverters
MPPT	-	Maximum Power Point Tracking
PFC	-	Power Factor Correction
ABC	-	Artificial Bee Colony
COA	-	Cuckoo Optimization Algorithm
ELR	-	Egg Laying Radius
FA	-	Firefly Algorithm
GUI	-	Graphical User Interface

CHAPTER 1

INTRODUCTION

Generally islands have the most carbon-intensive primary energy supply, because of its strong reliance on oil and lignite. 55% of the domestic energy demand is met with oil, approximately 99% of which is imported. For the oil energy needs of the islands in the Aegean alone, Greece pays more than 500 million Euro a year, in order to generate electricity at local power plants. The relatively high cost of electricity of isolated areas and non interconnected islands increases the competitiveness and promotes the wider incorporation of renewable energy technologies that may, in other cases, seem economically inferior to business-as usual energy solutions. With this in mind and accounting for the high potential of the country in renewable sources, it is expected that appropriate energy policies could make a significant contribution to the economic recovery of islands.

The goals of the project is to:

- Address the renewable energy autonomy of an island, including energy storage systems,
- Involve the people of the community in the decision-making process,
- Perform detailed technical calculations through simulations, as well as economic and environmental analyses,
- Propose a concrete energy
- Plan for achieving 100% sustainable living and
- Create the first guide on sustainable development based on social, environmental and economic data.

In recent days, generating electrical energy by renewable sources such as wind, solar and wave are becoming very important since the demand of electrical energy is increasing rapidly and the fossil fuel sources are limited. Among these renewable sources, wind is highly popular and wind conversion systems technology already plays an important role in power production. Since power is proportional to the cube of wind speed, the location of wind turbine becomes important. Therefore, building offshore wind farm is a good alternative to extract maximum power due to high average wind speed. With this wind speed, Concentrated Solar Power (CSP) plant is added to form the hybrid system comprising of an energy storage system. The addition of the CSP system would create a hybrid project that maintains or improves the power output.

In this project Vienna rectifier is used in wind system for power factor correction and to reduce power quality problems. The switching losses, number of MOSFETs are reduced by using Vienna rectifier. The system control is achieved by using Artificial Bee Colony (ABC) algorithm and Cuckoo Optimization Algorithm (COA) to attain the stability of the system in a short period of time. The efficiency of the system is improved. The output efficiency and the accuracy of the system is analyzed and verified by simulating the system using MATLAB Simulink.

CHAPTER 2

LITERATURE REVIEW

2.1 SIMULATION AND EVALUATION OF A HYBRID CONCENTRATING SOLAR AND WIND POWER PLANT FOR ENERGY AUTONOMY ON ISLANDS

Renewable energy sources can offer isolated communities the opportunity to regulate their energy use in a manner that best suits their needs. This paper presents the simulation and thermodynamic evaluation of a stand-alone hybrid power plant exclusively using renewable energy sources and storage technologies for the energy autonomy of a Mediterranean island. The study assumes stand-alone dynamic operation and investigates the sustainable and robust energy independence of the community under consideration, a remote area not connected to a centralized electrical grid. The analysis shows that the evaluated hybrid concentrating solar-wind power plant is a reliable alternative for satisfying the fluctuating electricity demand of the island. The plant achieves stable and controlled autonomous performance using the complementary character of solar and wind energy, combined with energy storage.

2.2 ENERGY MANAGEMENT FOR A STAND-ALONE PHOTOVOLTAIC WIND SYSTEM SUITABLE FOR RURAL ELECTRIFICATION

The renewable energy based installation situated in an isolated area is composed of photovoltaic panels, a wind turbine and a battery bank, which supply a non-controllable load. An energy management algorithm is proposed to decide on the switching between the installation components. The control decisions depend on the generated photovoltaic and wind turbine powers, the battery bank state of charge and the non-controllable load power demands. A fuzzy algorithm, which ensures the system's autonomy, a continuous load supply and safe operation for the battery bank, is used to decide on the connection of the installation's components. Then, using the genetic algorithm, a cost optimization of the installation operation is introduced to decide on the contribution of each power source in supplying the loads. Using measured meteorological data of the target area, the algorithm is extensively tested and the obtained results show the efficiency of the proposed algorithm in maximizing the use of the renewable energies, minimizing the installation's operation cost, guaranteeing the installation's autonomy even under climatic parameters changes while also ensuring a safe operation of the battery bank.

2.3 OPTIMAL CONFIGURATION OF HYBRID POWER GENERATION SYSTEM

Wind-solar hybrid power utilizing the wind and complimentary solar can improve the continuity of load power. An optimal configuration of wind solar hybrid power generation system is carried out. Correlation between wind power and solar power is analyzed by least squares method and to calculate marginal probability density of wind speed mean and variance estimation method is employed to obtain sunshine. Copula function is applied to calculate the joint probability density of wind power and solar power. The objective function of the optimization framework and constraint conditions are established according to the characteristics of wind solar hybrid power generation system. Genetic algorithm is used to optimize the objective function.

2.4 PERFORMANCE EVALUATION OF PV-WIND HYBRID ENERGY SYSTEM

The wind and solar PV system are connected to the common load through DCIDC Boost converter. Generally, in low radiation PV array system inverter gives the lower voltage than the rated voltage which affects the power quality. It is overcome by using Battery Energy Storage System. In the stand-alone mode the converter needs to maintain constant voltage and frequency regardless of load imbalance or the quality of the current, which can be highly distorted, if the load is nonlinear.

2.5 EFFICIENT CONTROL OF HYBRID GENERATION SYSTEM FOR DOMESTIC AND LOWER APPLICATIONS

The control strategy for the interconnection of the hybrid energy system is able to regulate the load’s voltage and controlling the energy generation with the energy options. The control strategy contains controlling the energy generated through each energy source, in a hierarchical mode using sliding/dropping mode control, while consuming consideration elements that have an impact on each electrical power source and transform the energy generated in order to suitable circumstances for lower power and domestic programs. The cross alternative energy system consists of photovoltaic cellular material, fuel cellular material and battery packs. A numerical equation in order to estimate the perfect voltage involving photovoltaic systems for virtually every solar irradiance and temperature circumstances is suggested.

2.6 A REVIEW ON MAXIMUM POWER POINT TRACKING ALGORITHMS FOR HYBRID GENERATION SYSTEM

Renewable energy sources can offer isolated communities the chance for employment to regulate their energy use in a manner that best suits their needs. This paper presents the various Maximum Power Point Tracking (MPPT) algorithms for a hybrid power plant consisting of solar and wind. Using MPPT algorithms maximum power is tracked from PV and wind energy sources. However, choosing an exact MPPT algorithm for a particular case is required for sufficient proficiency because each algorithm has its own merits and demerits. The merits, demerits and comprehensive comparison of the different MPPT algorithms are presented in the terms of complexity, wind speed requirement, response curves, switching rate, higher lifetime and efficiency. And also the ability to acquire the maximal energy output is recommended.

2.7 THREE PHASE POWER FACTOR CORRECTION, USING VIENNA RECTIFIER APPROACH AND MODULAR CONSTRUCTION

While applications for 1-Phase PFC are now familiar and prevalent, the same is not the case with 3-Phase PFC. Many equipments using kilowatts of power from 3-Phase mains should be candidates of 3-Phase power factor correction, because several advantages ensue, both to the user of the equipment and to the utility. The Vienna Rectifier approach to achieve 3-Phase power factor correction offers many advantages and convenient, user-friendly features as compared to the two-level, six-switch boost PWM Rectifier. Amongst them are: continuous sinusoidal input currents with unity power factor and extremely low distortion; no need for a neutral wire; reduction in voltage stress and switching losses of power semiconductors by almost 40%; immunity towards variation or unbalance in mains 3-Phase voltages or absence of one of the phases; very low conducted common-mode EMI/RFI; very high efficiency of the order of 97.5%, say, for power levels of 10 KW and input line voltage of 400 VAC and short circuit immunity to failure of control circuit. The paper describes the Vienna Rectifier's power stage and control techniques, with particular emphasis on modular construction.

2.8 ENHANCED ARTIFICIAL BEE COLONY OPTIMIZATION

In Enhanced Artificial Bee Colony (ABC) optimization algorithm, the onlooker bee is designed to move straightly to the picked coordinate indicated by the employed bee and evaluates the fitness values near it in the original Artificial Bee Colony algorithm in order to reduce the computational complexity. Hence, the exploration capacity of the ABC is constrained in a zone. Based on the framework of the ABC, the IABC (Interactive Artificial Bee Colony algorithm) introduces the concept of universal gravitation into the consideration of the affection between employed bees and the onlooker bees. By assigning different values of the control parameter, the universal gravitation should be involved for the IABC when there are various quantities of employed bees and the single onlooker bee. Therefore, the exploration ability is redeemed about on average in the IABC.

2.9 A SIMPLE AND EFFICIENT ARTIFICIAL BEE COLONY ALGORITHM

ABC is a new population-based stochastic algorithm which has shown good search abilities on many optimization problems. However, the original ABC shows slow convergence speed during the search process. In order to enhance the performance of ABC, this paper proposes a new artificial bee colony (NABC) algorithm, which modifies the search pattern of both employed and onlooker bees. A solution pool is constructed by storing some best solutions of the current swarm. New candidate solutions are generated by searching the neighborhood of solutions randomly chosen from the solution pool.

2.8 CUCKOO OPTIMIZATION ALGORITHM

This optimization algorithm is inspired by the life of a bird family, called Cuckoo. Special lifestyle of these birds and their characteristics in egg laying and breeding has been the basic motivation for development of this new evolutionary optimization algorithm. Similar to other evolutionary methods, Cuckoo Optimization Algorithm (COA) starts with an initial population. The cuckoo population, in different societies, is in two types: mature cuckoos and eggs. The effort to survive among cuckoos constitutes the basis of Cuckoo Optimization Algorithm. During the survival competition some of the cuckoos or their eggs, demise. The survived cuckoo societies immigrate to a better environment and start reproducing and laying eggs. Cuckoos' survival effort hopefully converges to a state that there is only one cuckoo society, all with the same profit values. Application of the proposed algorithm to some benchmark functions and a real problem has proven its capability to deal with difficult optimization problems.

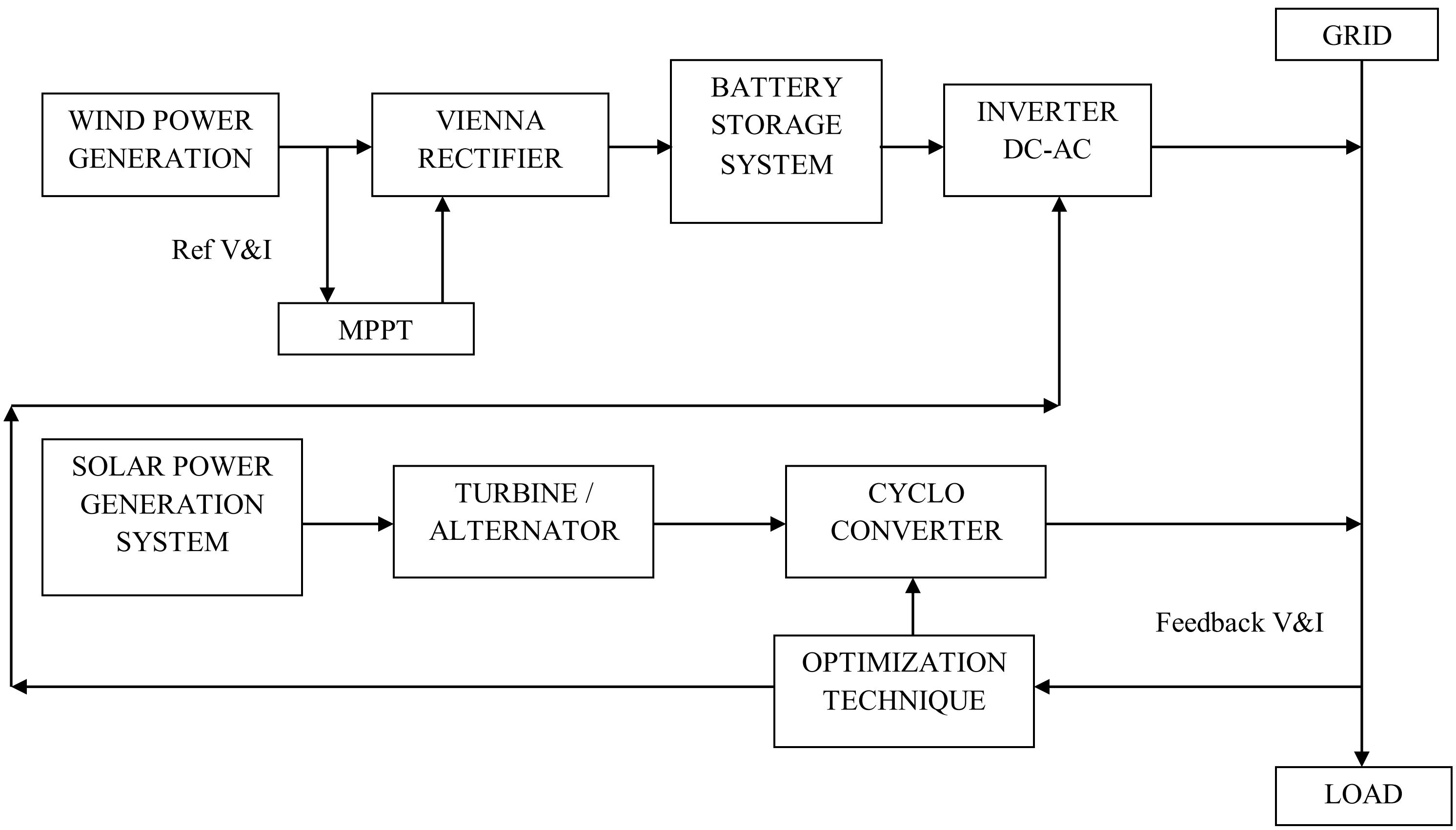
2.10 MODIFIED CUCKOO SEARCH: A NEW GRADIENT FREE ALGORITHM

A new robust optimization algorithm, which can be regarded as a modification of the recently developed cuckoo search, is presented. The modification involves the addition of information exchange between the top eggs, or the best solutions. Standard optimization benchmarking functions are used to test the effects of these modifications and it is demonstrated that, in most cases, the modified cuckoo search performs as well as, or better than, the standard cuckoo search, a particle swarm optimizer, and a differential evolution strategy. In particular the modified cuckoo search shows a high convergence rate to the true global minimum even at high numbers of dimensions.

CHAPTER 3

PROPOSED METHODOLOGY

3.1 BLOCK DIAGRAM



3.2 WIND POWER PLANT

Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air can extract part of the energy and convert into useful work.

Following factors control the output of wind energy converter:

- The wind speed
- Cross-section of the wind swept by rotor
- Conversion efficiently of rotor

- Generator
- Transmission System

Theoretically it is possible to get 100% efficiency by halting and preventing the passage of air through the rotor. However, a rotor is able to decelerate the air column only to one third of its free velocity. A 100% efficient wind generator is able to convert maximum up to 60% of the available energy in wind into mechanical energy. In addition to this, losses incurred in the generator or pump decrease the overall efficiency of power generation to 35%.

3.2.1 PRINCIPLE OF WIND ENERGY CONVERSION

Wind mills or turbines works on the principle of converting kinetic energy of the wind in to mechanical energy. Power available from wind mill = ½ þA V^3

Where, þ – air density = 1.225 Kg. / m^3 at sea level. (changes by 10-15% due to temperature and pressure variations)

A – Area swept by windmill rotor = þD^2 sq-m. (D – Diameter)

V – Wind speed m/sec.

Air density, which linearly affects the power output at a given speed, is a function of altitude, temperature and barometric pressure. Variation in temperature and pressure can affect air density up to 10 % in either direction. Warm climate reduces air density.

This equation tells us that maximum power available depends on rotor diameter. The combined effects of wind speed and rotor diameter can be observed by the following graph

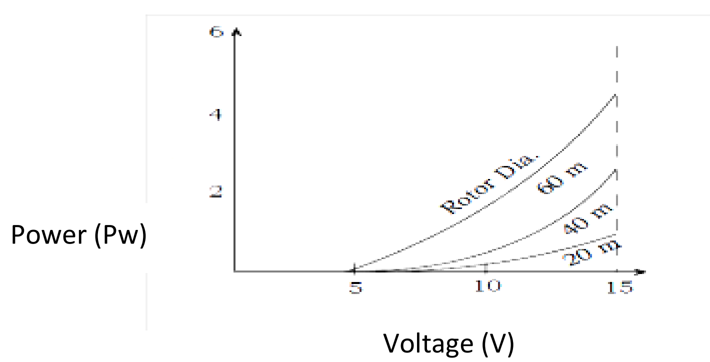


Figure 3.1 Combined effects of wind speed

This graph indicates that wind machines should have large rotors and should be located in areas of high wind speeds.

Practically, wind turbines are able to convert only a fraction of available wind power into useful power. As the free wind stream passes through the rotor, it transfers some of its energy to the rotor and its speed decreases to a minimum in the rotor wake. After some distance from the rotor wind stream regains its speed from the surrounding air. We can also observe drop in pressure as the wind stream passes through the rotor. Finally air speed and pressure increases to ambient atmospheric condition.

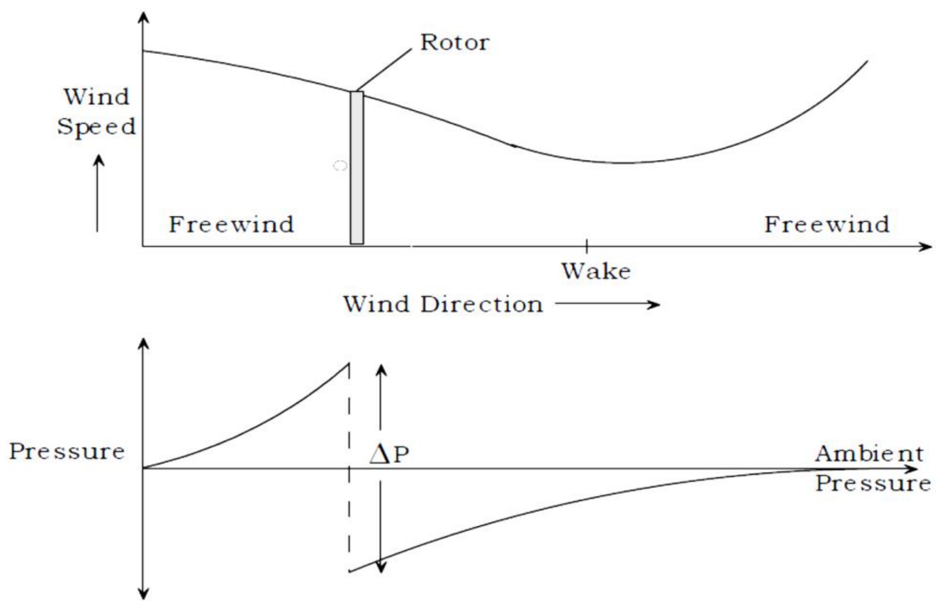


Figure 3.2 Wind speed Vs pressure

3.2.2 GENERATING SYSTEM

Wind - electric conversion system consists of the following components:

1) Wind Turbine (WT) - Converts wind energy into rotational (mechanical) energy

2) Gear system and Coupling (G/C) - It steps up the speed and transmits it to the generator rotor

3) Generator (G) - Converts rotational energy into electrical energy.

Types of generators used:

- Small rating systems – Permanent Magnet type d.c. generators
- Medium rating systems – Permanent Magnet type d.c. generators
- Medium rating induction generators
- Large rating synchronous Generators
- Large rating systems - Induction generators (3-phase)

4) Controller(C)-Senses wind direction, wind speed generator output and temperature and initiates appropriate control signals to take control action.

5) Yaw motor gear- The area of the wind stream swept by the wind turbine is maximum when blades face into the wind. Alignment of the blade angle with respect to the wind direction to get maximum wind energy can be achieved with the help of yaw control that rotates wind turbine about the vertical axis.

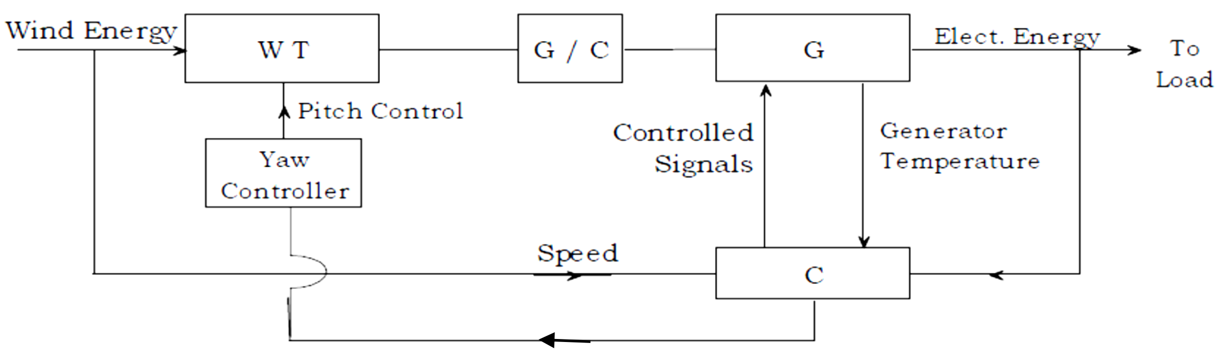


Figure 3.3 Flow diagram of wind energy

3.2.3 CROSS-SECTIONAL VIEW

Apart from the above components, protective schemes for excessive temperature rise of generator, against electrical faults and turbulent wind conditions are also provided in the system.

Practically, Wind power generating system ratings are divided into three groups:

- Small up to 1KW
- Medium 1 KW to 50 KW
- Large 200KW to Megawatts

3.2.4 WIND ELECTRIC CONVERSION SYSTEM

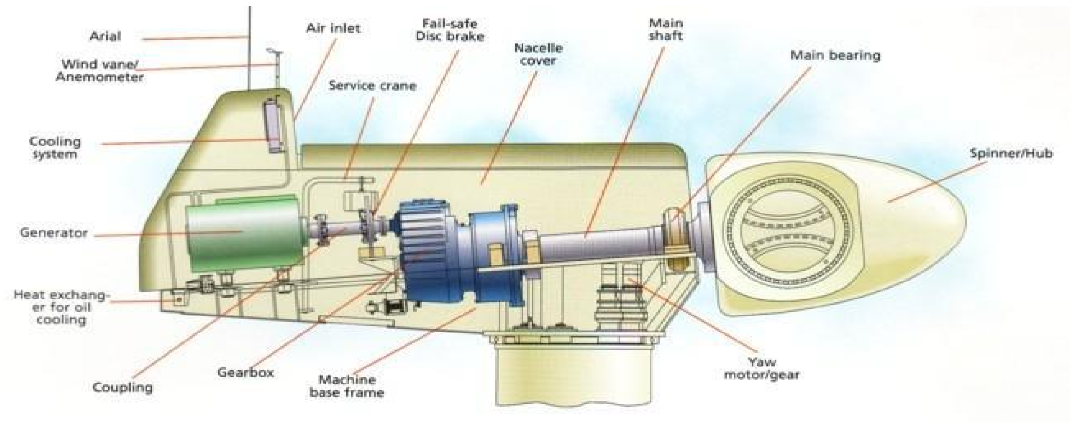


Figure 3.4 Wind – Electric energy conversion system

3.3 SCHEMES FOR WIND POWER GENERATION

Based on the speed and frequency, generally following schemes are identified:

3.3.1 CSCFS (Constant Speed Constant Frequency Scheme)

Constant speed drives are used for large generators that feed the generated power to the grid. Commonly synchronous generators or induction generators are used for power generation.

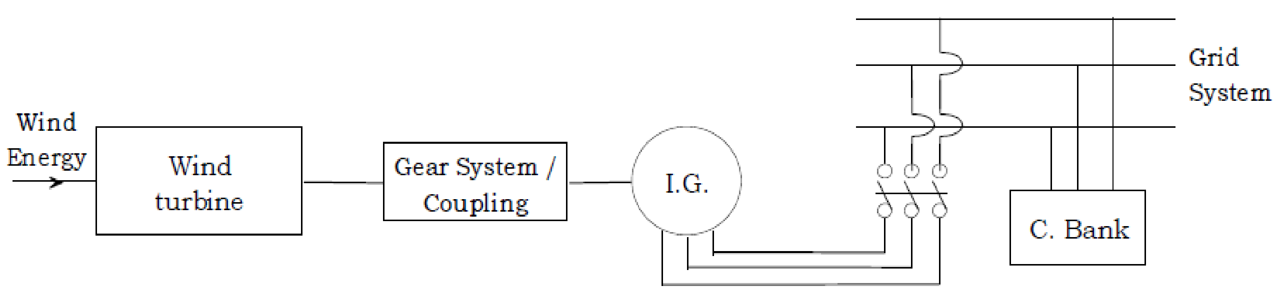


Figure 3.5 Constant speed constant frequency scheme

If the stator of an induction machine is connected to the power grid and if the rotor is driven above Synchronous speed N_s, the machine delivers a constant line frequency (f=PNs/120) power to the grid. The slip of the generators is between 0 and 0.05.The torque of the machine should not exceed maximum. Torque to prevent 'run away' (speed continues to increase unchecked).

Compared to synchronous generator, induction generators are preferred because they are simpler, economical, easier to operate, control and maintain and have no synchronization problem. However, capacitors have to be used to avoid reactive volt ampere burden on the grid.

3.3.2 DSCFS (Dual Speed Constant Frequency Scheme)

In this scheme a dual speed wind turbine is coupled to double winding. Induction generator that is specially fabricated with 2 stator windings wound with different number of poles P_1& P_2 ($P_1 > P_2$).

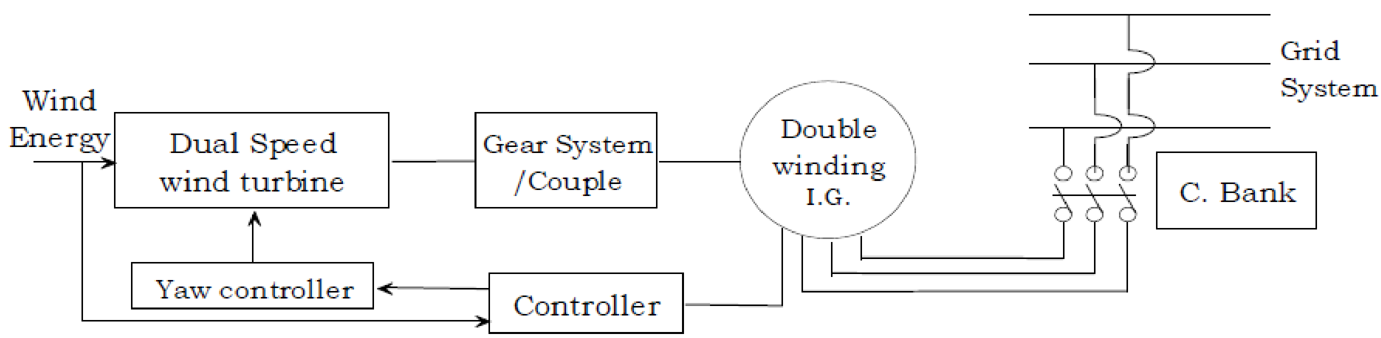


Figure 3.6 Dual speed constant frequency scheme

When wind speed is low, winding with P_1 poles gets connected and power is generated with grid frequency. Similarly, when wind speed is high, winding with P_2 poles gets connected and feed the power to grid at the same frequency. It is important to note that the difference in speed should be small. Reactive power required by the Induction Generator can be supplied by installing the capacitor bank.

3.3.3 VSCFS (Variable Speed Constant Frequency Scheme)

In this scheme output of three phase alternator is rectified by bridge rectifier. The DC output is transmitted through DC transmission lines and then converted back to AC using synchronous inverters and fed to grid system.

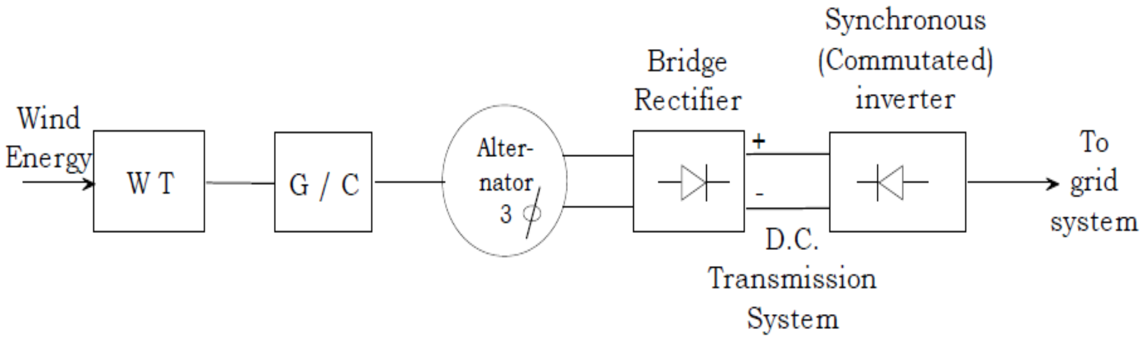


Figure 3.7 Variable speed constant frequency scheme

This scheme, involving small wind generators is commonly used in autonomous applications such as street lighting. Due to variable speed operation, it yields higher power for both low and high wind speeds. Both horizontal axis and vertical axis turbines are suitable.

3.3.4 VSCF with DO (Variable Speed Constant Frequency with Double Output)

In this scheme, to increase the power generating capacity of the system, squirrel cage induction generators are replaced by slip ring Induction generator. Rotor power output at slip frequency is converted to line frequency power using rectifier. Output power is obtained both from stator and rotor. Rotor output power increases with increase in slip and speeds. Therefore, operating speed range is Ns to 2Ns i.e. slip ranging from 0 to 1.

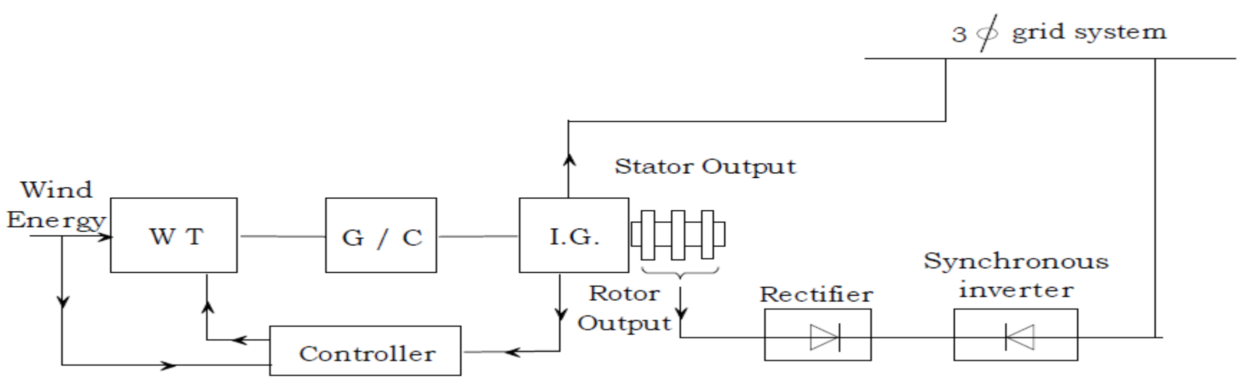


Figure 3.8 Variable speed constant frequency with double output

3.3.5 VSVFS (Variable Speed Variable Frequency Scheme)

This scheme is suitable for loads that are frequency insensitive such as heating load.

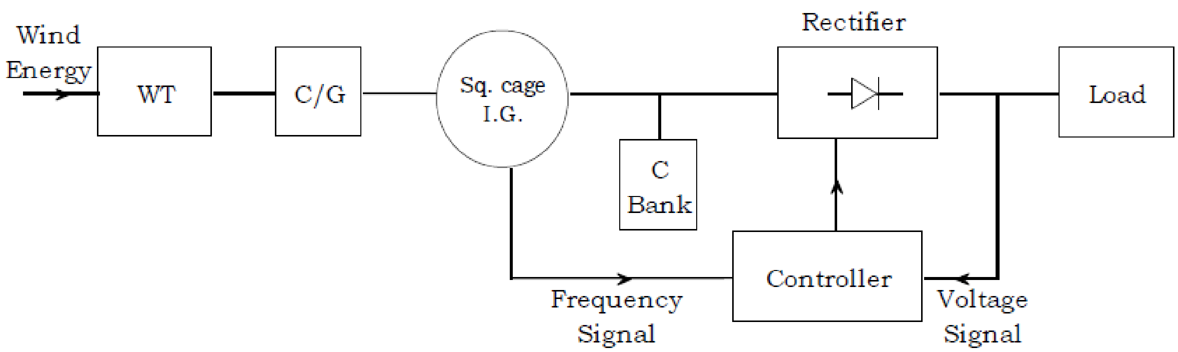


Figure 3.9 Variable speed variable frequency scheme

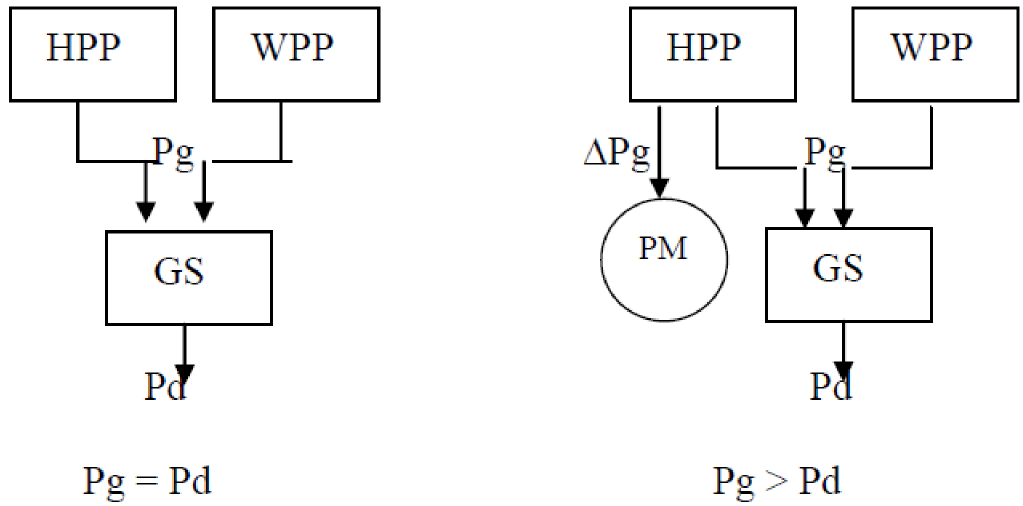
Depending upon the wind speed, squirrel cage Induction Generator generates power at variable frequency. Such generators are excited by Capacitor-bank. The magnitude and frequency of the generated emf depends upon the wind turbine speed, excitation capacitance and load impedance. If load requires constant dc voltage, output of generators is converted into D.C using chopper controlled rectifiers. Feedback system can be used to monitor and control to get desired performance.

Among all the above schemes VSVFS is preferred because of the varying wind speed due to environmental conditions.

3.4 ENERGY STORAGE

Wind power turbines have operational limitations over very high and very low speeds. When the power generated exceeds the demand, excess energy can be stored to be used at other times.

- Excess energy can be conveniently stored in storage batteries in the form of chemical energy.
- Excess energy can also be stored in water power storage in the form of mechanical energy. Wind Power Plant (WPP) along with Hydroelectric Power Plant (HPP), when generated power (P_g) exceeds the power demand (P_d), helps to partly divert hydro power plant output to Pumping Motor (PM) to pump water from an auxiliary reservoir at the bottom of the dam to main reservoir.



- Excess energy can also be stored in the form of compressed air.

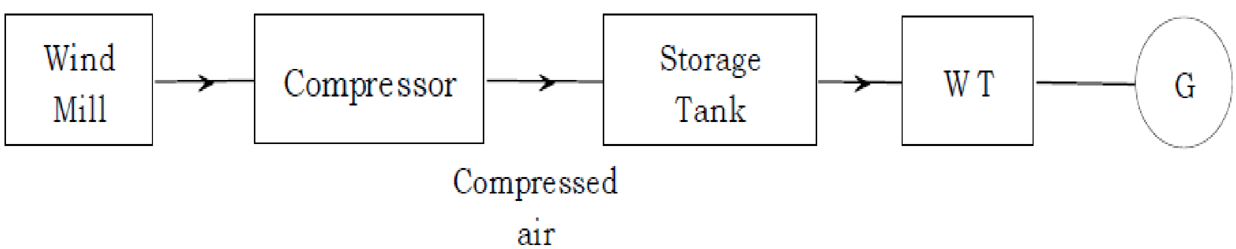


Figure 3.10 Energy storage system

When wind is not blowing, energy stored in compressed air could be used to drive wind turbine whose shaft would then drive a generator, thus supplying the needed power.

3.5 VIENNA RECTIFIER

The Vienna rectifier was introduced in 1993 by Prof. Johann W. Kola. It is a three phase, three levels and three switch rectifier; it is a kind of PWM (Pulse Width Modulation) rectifier with controlled output voltage. The topology of the Vienna Rectifier is a combination of a boost DC\DC converter with a three-phase diode bridge rectifier. Figure 3.11 illustrates this rectifier circuit.

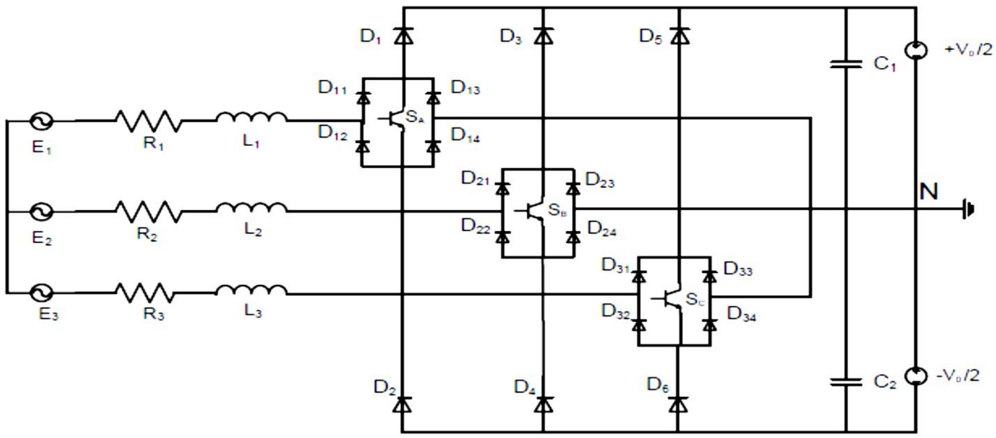


Figure 3.11 Vienna rectifier

Across each capacitor, two voltage sources $+V_0/2$ and $-V_0/2$ exist which detect the output voltage of the circuit. Therefore three different voltages ($+V_0/2$, 0, $-V_0/2$) are available. The DC bus voltage is assumed to be a constant dc voltage and can be connected to a conventional six switch or other type of inverter.

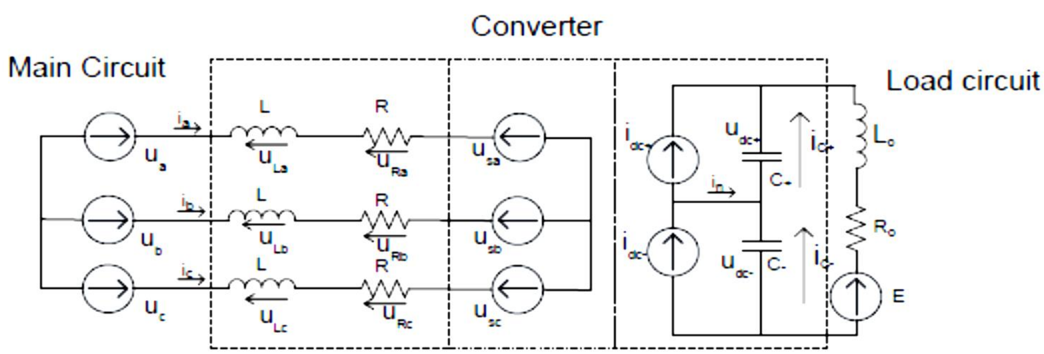


Figure 3.12 Vienna rectifier equivalent schematic diagram

The input current for each phase is defined by the voltage applied across the corresponding inductor L_N; the input voltage of the rectifier is determined by the switching state and the input current direction. The input inductors (L_N) charge when the switch is on and the current increase in the inductor, and when the switch is off the inductors discharge through the positive or negative diode depending on the current flow direction. The existence of an input inductor creates a current source at the input while the capacitors create output voltages. In other words, the Vienna rectifier may be considered as a diode–transistor matrix connecting the input current sources with output voltages. Figure 3.12 shows an equivalent schematic diagram for the Vienna rectifier.

The advantages of Vienne rectifier over other power electronic converters are given below:

- Continuous sinusoidal input current
- No need for a neutral wire
- Low number of IGBTs used
- Low manufacturing cost
- Reduce blocking voltage stress on power semiconductor.
- Reduction in switching loss of the power semiconductors by almost 40%.
- Wide voltage range.
- Higher efficiency.
- Boosting ability.
- Production of three levels of voltage with two equal DC voltages.

3.5.1 OPERATION OF THE VIENNA RECTIFIER

The Vienna rectifier has three switches, and by choosing their (ON\OFF) state considering the polarity of the phase current in each phase, the voltage for each phase will be determined. So, the phase voltage is depending on the direction of phase current and switch position. In this topology, the midpoint N is considered as reference point with zero voltage. Therefore, the phase voltage is described as,

$$L_N \frac{di_k}{dt} = E_N - V_{KN}$$

----------- (1)

When the phase current is positive,

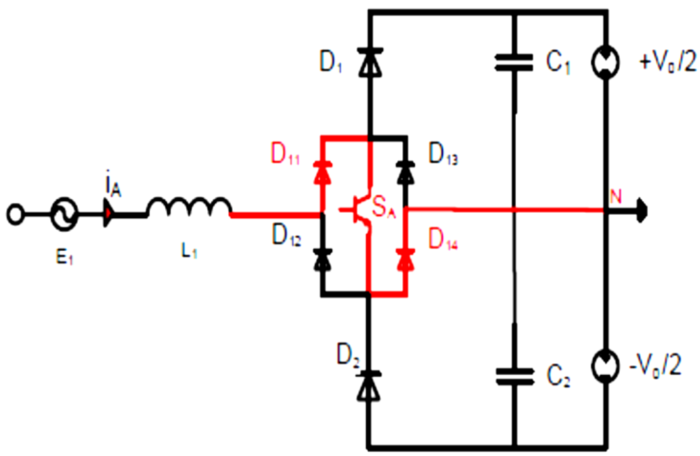
$$V_{KN} = \begin{cases} \frac{+V_0}{2} & S_k = 0 \\ 0 & S_k = 1 \end{cases}$$

--------------- (2)

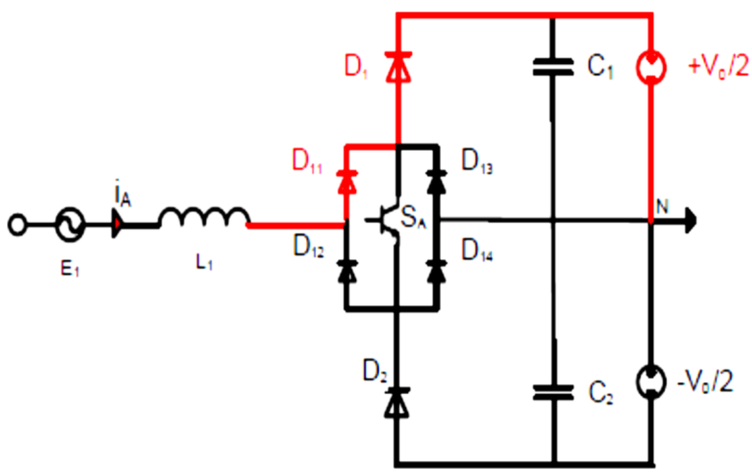
and when the phase current is negative,

$$V_{KN} = \begin{cases} \frac{-V_0}{2} & S_k = 0 \\ 0 & S_k = 1 \end{cases} \quad \text{---------------- (3)}$$

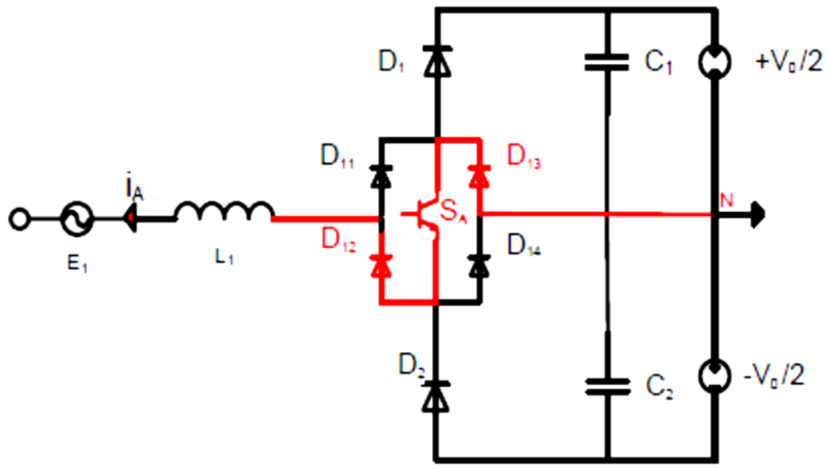
where L_N are the input inductors (N=1,2,3), i_k is the input phase current, V_{KN} is the phase voltage (K =A,B,C), S_k is a controlled switch (S_k = 0 correspond to off state and S_k = 1 to the on state). Figure 3.13 shows the behavior of phase A. Phases B and C behave the same pattern.



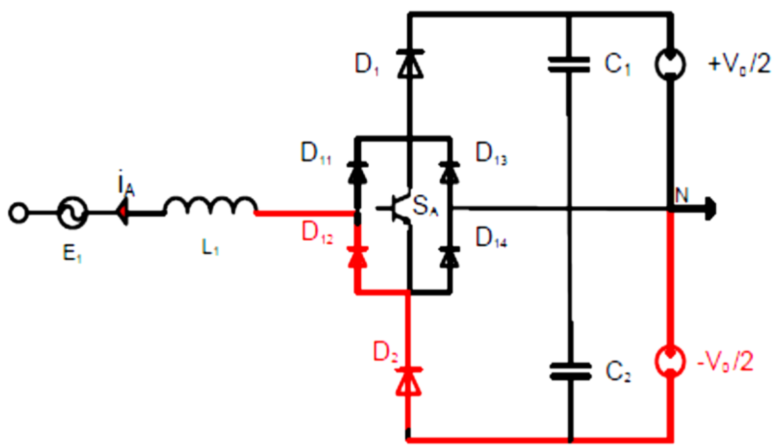
(a) Line current is positive and S_A is ON



(b) Line current is positive and S_A is OFF



(c) Line current is negative and S_A is ON

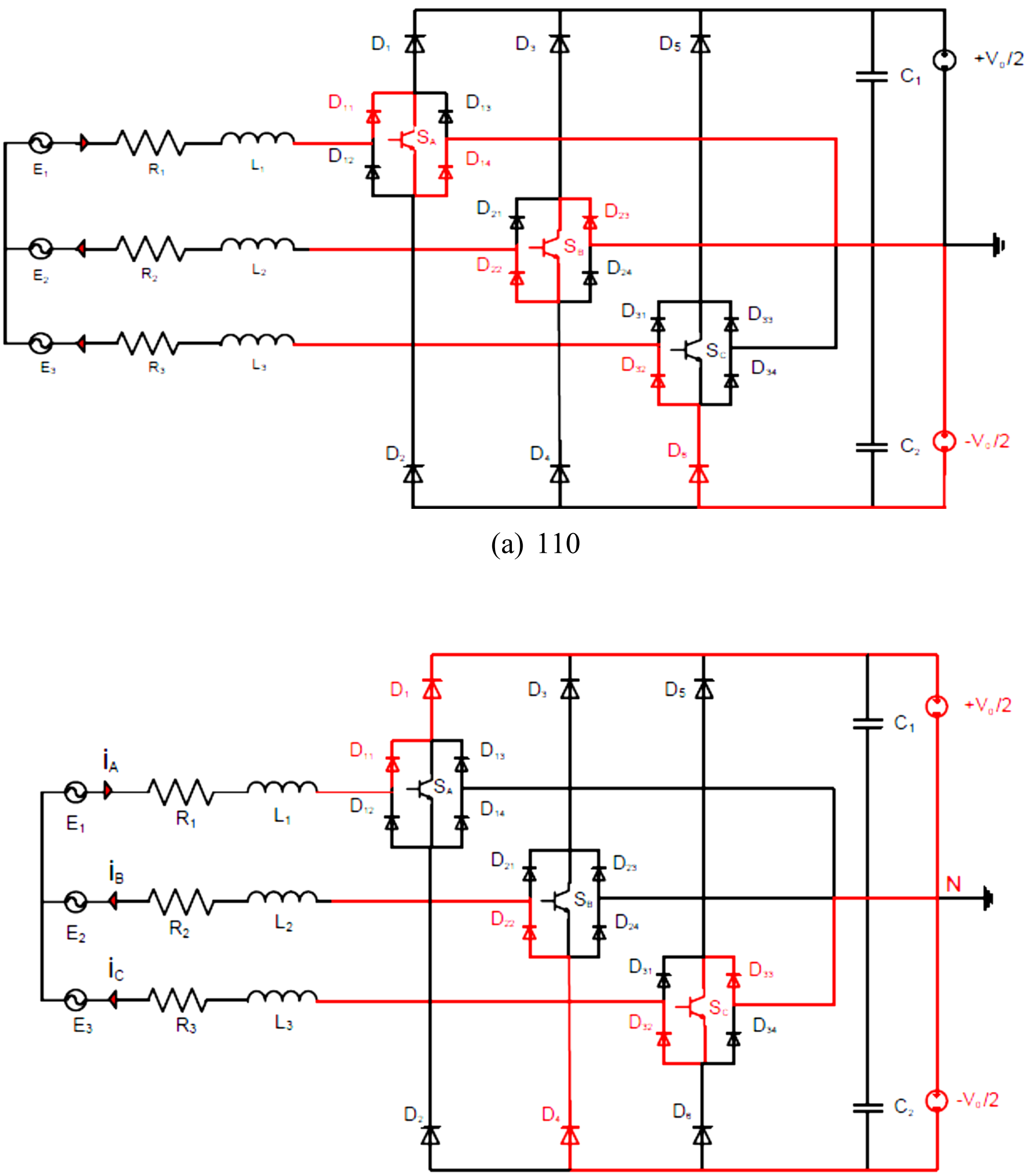


(d) Line current is negative and S_A is OFF

Figure 3.13 Conduction path for phase A

If the line current is positive and switch S_A is ON (Figure 3.13(a)); the current pass through the switch and the phase voltage (V_{AN}) become zero. If the polarity of the current remains as before but the control switch SA is off, the current flows through diode D_{11}, the voltage V_{AN} is $+V_0/2$, Fig. 3.13(b) illustrates this case. Similarly, the voltage V_{AN} can determined if the line current is negative and switch S_A is ON or OFF, the current path for these two cases is illustrated in Figure 3.13 (c), (d).

The current path for two example switching position, 110 and 001, are shown in Figure 3.14.



(a) 110

(b) 001

Figure 3.14 Current path for two switching positions

If it is assumed that the current for phase A is positive and it is negative for both phase B and C. Then eight different switching positions can be considered, given the results shown in Table 3.1.

Table 3.1 Eight different switching combination

S_A	S_B	S_C	V_{AN}	V_{BN}	V_{CN}
0	0	0	$+V_0/2$	$-V_0/2$	$-V_0/2$
0	0	1	$+V_0/2$	$-V_0/2$	0
0	1	0	$+V_0/2$	0	$-V_0/2$
0	1	1	$+V_0/2$	0	0
1	0	0	0	$-V_0/2$	$-V_0/2$
1	0	1	0	$-V_0/2$	0
1	1	0	0	0	$-V_0/2$
1	1	1	0	0	0

3.5.2 VOLTAGE SPACE VECTOR

As mentioned before, the voltage space vector is one way to visualize the Vienna rectifier‘s output voltage for different switching patterns. The basic voltage space vector is consisting of six zones where the current signs can have different values.

$$Zone = \begin{cases} 0 & if\ i_A = positive\ ; i_B = negative; i_C = negative; \\ 1 & if\ i_A = positive\ ; i_B = positive; i_C = negative; \\ 2 & if\ i_A = negative\ ; i_B = positive; i_C = negative; \\ 3 & if\ i_A = negative\ ; i_B = positive; i_C = positive; \\ 4 & if\ i_A = negative\ ; i_B = negative; i_C = positive; \\ 5 & if\ i_A = positive\ ; i_B = negative; i_C = positive; \end{cases} \quad \text{----------} (4)$$

Each of these zones describes one hexagon in the αβ reference frame and is settled with a π/3 difference angle with respect to each other. Each hexagon consists of eight different switching combinations; e.g. Table 3.1 refers to zone 0. Figure 3.15 describes these zones.

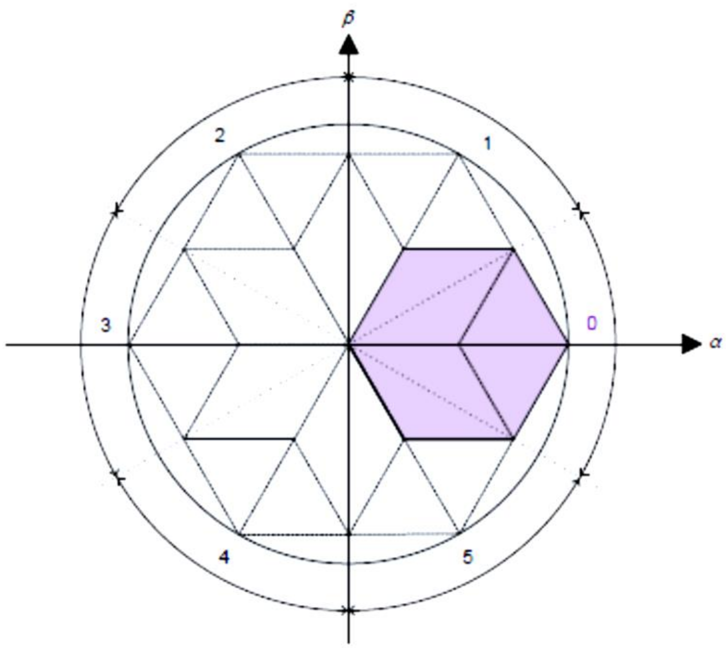


Figure 3.15 Voltage base space vectors of the Vienna rectifier

An important point in the controlling of the Vienna rectifier is the phase displacement angle (φ_s). This angle is defined between the fundamental current and the fundamental voltage at the AC side of the converter.

3.6 CONCENTRATING SOLAR POWERPLANT

Concentrating Solar Power (CSP) is the electricity generated from mirrors to focus sunlight onto a receiver that captures the sun's energy and converts it into heat that can run a standard turbine generator or engine. CSP systems range from remote power systems as small as a few kilowatts up to grid-connected power plants of 100's of megawatts (MW). CSP systems work best in bright, sunny locations like the Southwest. Because of the economies of scale and cost of operation and maintenance, CSP technology works best in large power plants.

- Clean, reliable power from domestic renewable energy
- Operate at high annual efficiencies – Firm power delivery when integrated with thermal storage
- Easily integrated into the power grid
- Boosts national economy by creating many new solar companies and jobs.

The limited supply of fossil hydrocarbon resources and the negative impact of CO2 emissions on the global environment dictate the increasing usage of renewable energy sources. Concentrated Solar Power (CSP) is the most likely candidate for providing the majority of this renewable energy, because it is amongst the most cost-effective renewable electricity technologies and because its supply is not restricted if the energy generated is transported from the world's solar belt to the population centres.

Three main technologies have been identified during the past decades for generating electricity in the 10 kW to several 1000 MW range:

- Parabolic trough technology - which produces high pressure superheated steam
- Dish/engine technology - which can directly generate electricity in isolated locations.
- Solar tower technology - which produces air above 1000°c or synthesis gas for gas turbine operation.

While these technologies have reached a certain maturity, as has been demonstrated in pilot projects in Israel, Spain and the USA, significant improvements in the thermo-hydraulic performance are still required if such installations are to achieve the reliability and effectiveness of conventional power plants. This first article focuses on present CSP technologies, their history and the state of the art. The second article, in the next issue of Ingenia, looks at the technical, environmental, social and economic issues relating to CSP in the future.

3.6.1 TECHNICAL PRINCIPLES

In general, solar thermal technologies are based on the concept of concentrating solar radiation to produce steam or hot air which can then be used for electricity generation using conventional power cycles. Collecting the solar energy, which has relatively low density, is one of the main engineering tasks in solar thermal power plant development. For concentration, most systems use glass mirrors because of their very high reflectivity. Other materials are under development to meet the needs of solar thermal power systems. Point focusing and line focusing systems are used, as depicted in Figure 3.16 These systems can use only direct radiation, and not the diffuse part of sunlight because this cannot be concentrated. Line focusing systems are easier to handle, but have a lower concentration factor and hence achieve lower temperatures than point focusing systems.

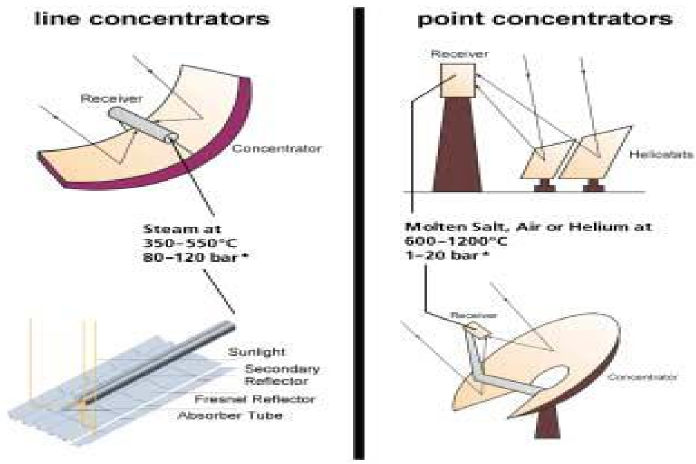


Figure 3.16 Technologies for concentrating solar radiation: left side parabolic and linear Fresnel troughs, right side central solar tower receiver and parabolic dish

Parabolic troughs, linear Fresnel systems and power towers can be coupled to steam cycles of 10 to 200 MW of electric capacity, with thermal cycle efficiencies of 30–40%. The values for parabolic troughs, by far the most mature technology, have been demonstrated in the field. Today, these systems achieve annual solar-to-electricity efficiencies of about 10–15%, with the aim that they should reach about 18% in the medium term. The values for other systems are, in general, projections based on component and prototype system test data, and the assumption of mature development of current technology. Overall solar-electric efficiencies are lower than the conversion efficiencies of conventional steam or combined cycles, as they include the conversion of solar radiative energy to heat within the collector and the conversion of the heat to electricity in the power block. The conversion efficiency of the power block remains essentially the same as in fuel fired power plants. Because of their thermal nature, each of these technologies can be 'hybridised', or operated with fossil fuel as well as solar energy. Hybridisation has the potential to improve dramatically the value of CSP technology by increasing its power availability and dispatchability, decreasing its cost (by making more effective use of the power block equipment), and reducing the technological risk by allowing conventional fuel use if, for example, the collector has to be repaired. Solar heat collected during the daytime can be stored in concrete, molten salt, ceramics or phase-change media. At night, it can be extracted from storage to run the power block. Fossil and renewable fuels such as oil, gas, coal and biomass can be used for co-firing the plant, thus providing power capacity whenever required. Moreover, solar energy can be used for co-generation of electricity and heat. In this case, the high value solar energy input is used with the best possible efficiencies of up to 85%. Possible applications include the combined production of electricity, industrial process heat, district cooling and sea water desalination. It is generally assumed that solar concentrating systems are economic for locations with direct incidence radiation above 1800 kWh m^{-2} $year^{-1}$.

3.6.2 TYPES OF CSP SYSTEMS

Parabolic Trough: Long, curved mirrors pivot to concentrate sunlight onto tubes filled with a heat transfer fluid, generally oil or water, whose steam moves a power-generating turbine. These systems are the most developed CSP technology and have operated in the United States since the 1980s. Optimal capacity size is 150-250 MW enough to power 44,000 homes – although 80 MW is the largest plant size today. Alternately, one U.S. company, Sopogy Inc., has created a “Micro CSP” system that uses a scaled-down parabolic trough system for distributed generation on rooftops.

Linear Fresnel Reflectors (LFR): Still in the demonstration stage, LFR systems function like parabolic trough systems but use flat mirror strips instead of curved mirrors. Although less efficient than other CSP systems, the cheaper expense of flat mirrors lowers initial investment cost.

Dish/Engine: Mirrored dishes (resembling those for satellite television) track the sun and concentrate its heat onto a power-generating unit that has an engine powered by a heat-responsive fluid. Stirling engines, the most common type of engine for this system, do not require the extensive water cooling system needed for steam engines because its engine is powered by the expansion-contraction of hydrogen gas as it is heated and cooled. The newest systems have 31.5 percent sun-to-grid energy conversion efficiency, the highest among CSP plants. However, they have a smaller production capacity of 0.003-0.025 MW. The first commercial deployment of a dish/Stirling system array is planned for 2010.

Power tower: Fields of flat mirrors focus sunlight onto a central receiver filled with a heat-transfer fluid, most often molten salt, which can trap thermal energy for long periods. These systems concentrate heat at higher temperatures than other CSP systems, improving their conversion efficiency. A 20 MW power tower system came online in April 2009 outside Seville, Spain, and the early Solar Two demonstration plant, a 10 MW facility that operated from 1996-1999 in Barstow, California, had a storage tank which provided three hours of electricity when the sun was not shining.

3.7 THREE PHASE INVERTER

A power inverter, or inverter, is an electronic device or circuitry that changes Direct Current (DC) to Alternating Current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. Here we use MOSFET switches for three phase inverter. Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium- to high-power applications.

The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable.

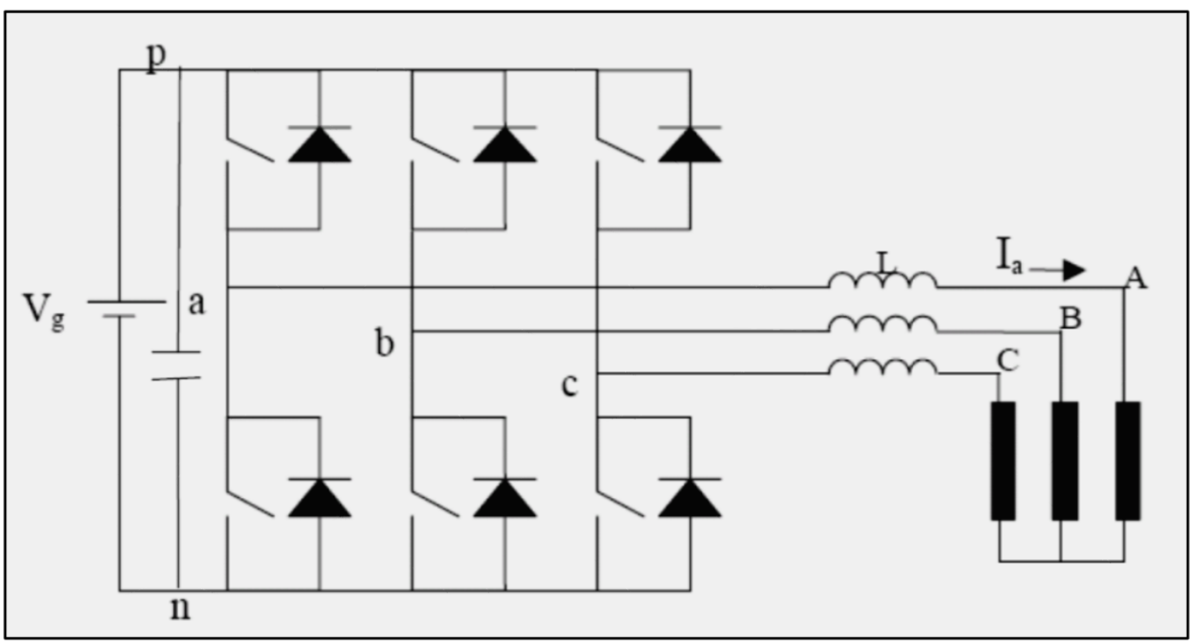


Figure 3.17 Three phase inverter

3.8 ENHANCED ARTIFICIAL BEE COLONY (ABC) OPTIMIZATIONALGORITHM

The ABC algorithm is proposed by Karaboga in 2005, and the performance of ABC is analyzed in 2007. The ABC algorithm is developed by inspecting the behaviors of the real bees on finding food source, which is called the nectar, and sharing the information of food sources to the bees in the nest. In the ABC, the artificial agents are defined and classified into three types namely the employed bee, the onlooker bee, and the scout. Each of them plays different role in the process: the employed bee stays on a food source and provides the neighborhood of the source in its memory; the onlooker gets the information of food sources from the employed bees in the hive and select one of the food source to gather the nectar; and the scout is responsible for finding new food, the new nectar, sources. The process of the ABC algorithm is presented as follows:

Step 1. Initialization: Spray n_e percentage of the populations into the solution space randomly, and then calculate their fitness values, which are called the nectar amounts, where n_e represents the ratio of employed bees to the total population. Once these populations are positioned into the solution space, they are called the employed bees.

Step 2. Move the Onlookers: Calculate the probability of selecting a food source by the equation (5), select a food source to move to by roulette wheel selection for every onlooker bees and then determine the nectar amounts of them. The movement of the onlookers follows the equation (6).

Step 3. Move the Scouts: If the fitness values of the employed bees do not be improved by a continuous predetermined number of iterations, which is called ”$Limit$”, those food sources are abandoned, and these employed bees become the scouts. The scouts are then moved by the equation (7).

Step 4. Update the Best Food Source Found So Far: Memorize the best fitness value and the position, which are found by the bees.

Step 5. Termination Checking: Check if the amount of the iterations satisfies the termination condition. If the termination condition is satisfied, terminate the program and output the results; otherwise go back to the Step 2.

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{S} F(\theta_k)} \qquad \text{———} \qquad (5)$$

where θ_i denotes the position of the ith employed bee, S represents the number of employed bees, and P_i is the probability of selecting the ith employed bee.

$$x_{ij}(t+1) = \theta_{ij} + \phi(\theta_{ij}(t) - \theta_{kj}(t)) \qquad \text{———} \qquad (6)$$

where x_i denotes the position of the ith onlooker bee, t denotes the iteration number, θ_k is the randomly chosen employed bee, j represents the dimension of the solution and $\phi(\cdot)$ produces a series of random variable in the range [−1, 1].

$$\theta_{ij} = \theta_{ij_{min}} + r \cdot (\theta_{ij_{max}} - \theta_{ij_{min}})| \qquad \text{———} \qquad (7)$$

where r is a random number and $r \in [0, 1]$.

3.8.1 PSEUDO CODE FOR ABC ALGORITHM

- Initialize the population of solutions $x_{i,j}$
- Evaluate the population
- Cycle=1
- Repeat
- Produce new solutions (food source positions) $\upsilon_{i,j}$ in the neighbourhood of $x_{i,j}$ for the employed bees and evaluate them
- Apply the greedy selection process between x_i and υ_i
- Calculate the probability values P_i for the solutions x_i by means of their fitness values
- Produce the new solutions (new positions) υ_i for the onlookers from the solutions x_i, selected depending on P_i, and evaluate them.
- Apply the greedy selection process for the onlookers between x_i and υ_i
- Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution x_i for the scout
- Memorize the best food source position (solution) achieved so far

- cycle=cycle+1
- until cycle= Maximum Cycle Number (MCN)

3.8.2 ADVANTAGES OF ABC ALGORITHM

The major advantages which ABC holds over other optimization algorithms include its:

- Simplicity, flexibility and robustness
- Use of fewer control parameters compared to many other search techniques
- Ease of hybridization with other optimization algorithms
- Ability to handle the objective cost with stochastic nature
- Ease of implementation with basic mathematical and logical operations
- Broad applicability even in complex functions
- Ease of implementation
- Ability to explore local solutions
- Ability to handle the objective cost

3.8.3 LIMITATIONS OF ABC ALGORITHM

- Lack of use of secondary information
- Requires new fitness tests on the new algorithm parameters
- Possibility of losing relevant information
- High number of objective function evaluations
- Slow response in sequential processing
- High computational cost
- More computational complexity

3.8.4 APPLICATIONS OF ABC

- Benchmarking optimization
- Bioinformatics application
- Scheduling applications
- Clustering and mining applications

3.8.5 FLOWCHART FOR ABC ALGORITHM

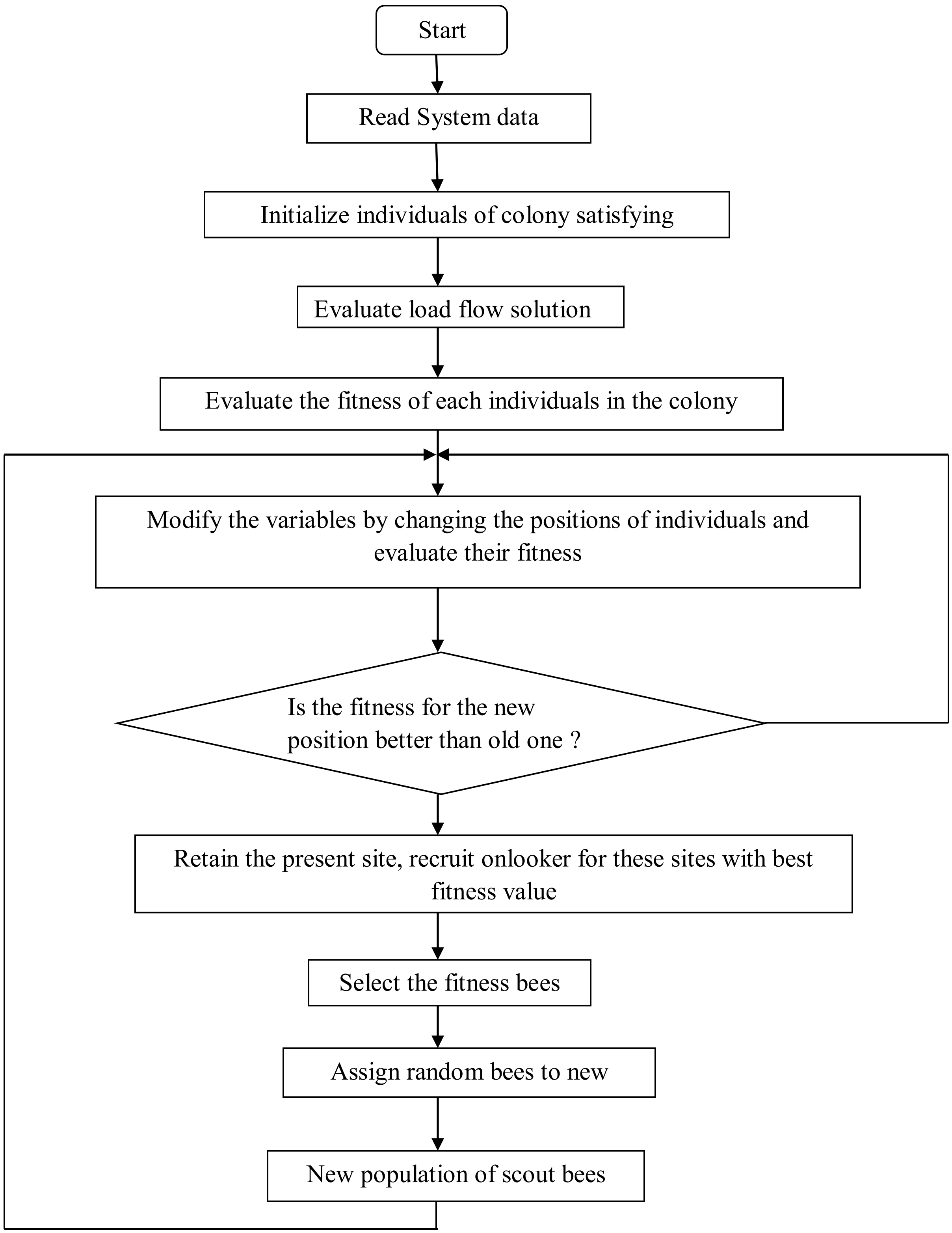


Figure 3.18 Flowchart of ABC algorithm

3.9 CUCKOO OPTIMIZATION ALGORITHM

Cuckoo Optimization Algorithm, which is inspired by lifestyle of a bird family called cuckoo has been introduced by Rajabioun. Specific egg laying and breeding of cuckoos is the basis of this algorithm. Cuckoos used in this modeling exist in two forms: mature cuckoos and eggs. Mature cuckoos lay eggs in some other birds' nest and if these eggs are not recognized and not killed by host birds, they grow and become a mature cuckoo. Environmental features and the immigration of societies (groups) of cuckoos hopefully lead them to converge and find the best environment for breeding and reproduction. This best environment is the global maximum of objective functions.

To solve optimization problem using COA first habitat matrix must be generated. For this population size must be determined. Let N is population size and the search space is D-dimensional. Then, the position of i^{th} cuckoo is represented as

$$X_i = (x_{i1}, \quad x_{i2}, \quad \cdots \quad , x_{id}), \; i=1,2,\ldots N. \qquad \text{(8)}$$

Then, some randomly produced number of eggs is supposed for each of these initial cuckoo populations. In nature, each cuckoo lays from five to twenty eggs. These values are used as the upper and lower limits of egg dedication to each cuckoo at different iterations. Another habit of real cuckoos is that they lay eggs within a maximum distance from their habitat, which is called as "Egg Laying Radius (ELR)". The ELR is defined as:

$$ELR = \propto * \frac{\text{Number of current cuckoo's eggs}}{\text{Total number of eggs}} * (var_h - var_l) \qquad \text{(9)}$$

where, var_h is the upper limit and var_l is the lower limit of problem interval, α is an integer, supposed to handle the maximum value of ELR. After some iterations, all the cuckoo population moves to one best habitat with maximum similarity of eggs to the host birds and also with the maximum food resources. This habitat will produce the maximum profit ever.

3.9.1 FLOWCHART FOR CUCKOO ALGORITHM

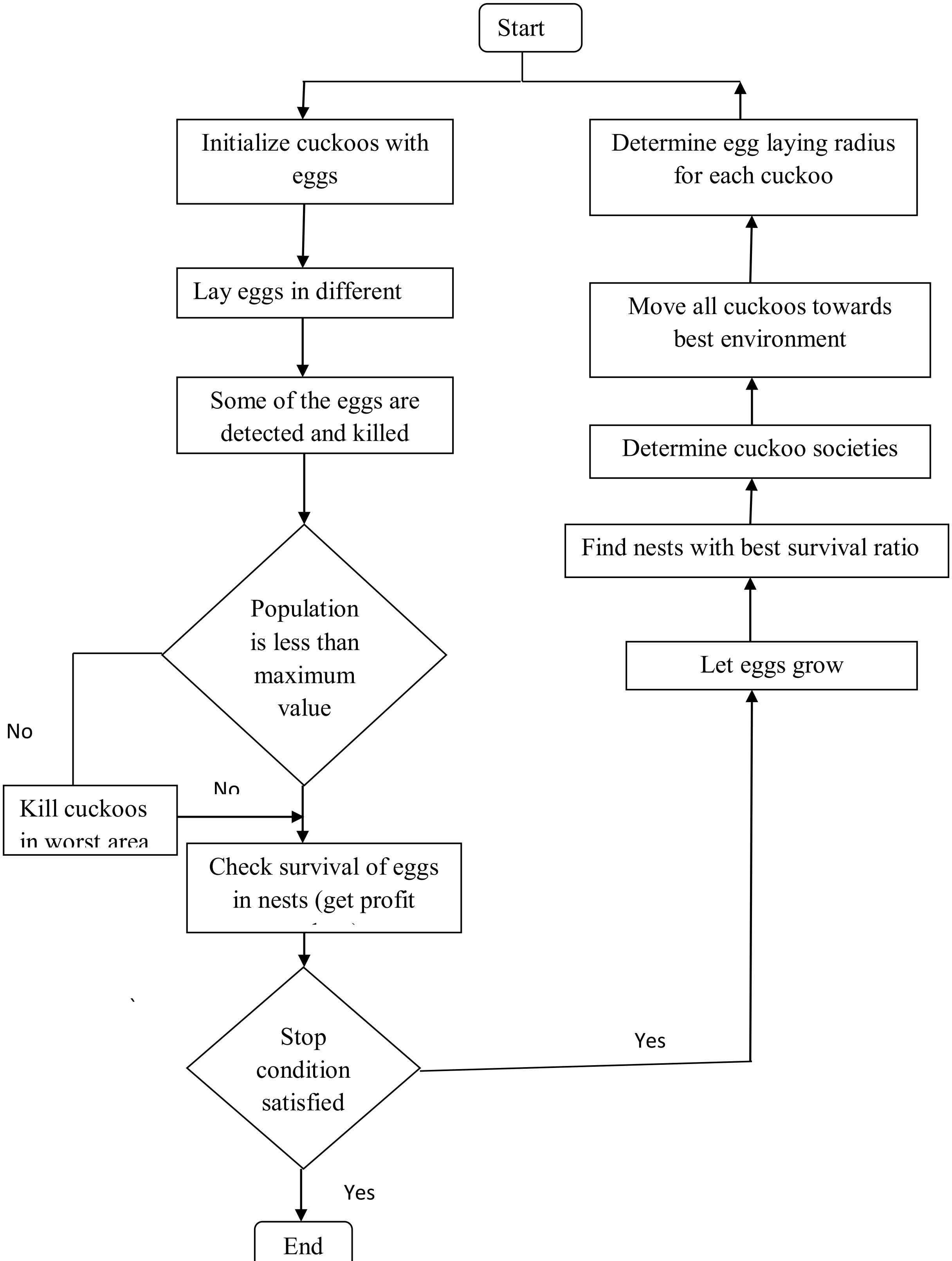


Figure 3.19 Flowchart of cuckoo optimization algorithm

3.9.2 PSEUDO CODE FOR CUCKOO ALGORITHM

- Initialize cuckoo habitats with some random points on the profit function
- Dedicate some eggs to each cuckoo
- Define ELR for each cuckoo
- Let cuckoos to lay eggs inside their corresponding ELR
- Kill the eggs which recognized by host birds
- Let eggs hatch and chicks grow
- Evaluate the habitat of each newly grown cuckoo
- Limit cuckoos' maximum number in environment and kill those who live in worst habitats
- Cluster cuckoos and find best group and select goal habitat
- Let new cuckoo population immigrate toward goal habitat
- If stop condition is satisfied stop, if not go to 2.

3.9.3 IDEALIZED RULE FOR CUCKOO SEARCH

- Each cuckoo lays one egg at a time, and dumps it in a randomly chosen nest
- The best nests with high quality eggs will carry over to the next generations
- The number of available host nests is fixed and a host discover an alien egg with probability.

3.9.4 ADVANTAGES OF CUCKOO SEARCH ALGORITHM

- Deals with multi-criteria optimization problems
- Easy to implement
- Simplicity
- Can be easily hybridized with other swarm based algorithms
- Aims to speed up convergence

3.9.5 APPLICATIONS OF CUCKOO SEARCH

- Engineering optimization algorithms

- NP hard problems
- Train neural network
- Manufacturing Scheduling
- Nano electric Technology
- Wind turbine blade
- Reliability problem
- Stability analysis

3.10 COMPARISON AND EVALUATION OF RESULTS

For evaluation and finding out efficiency of the COA, the Rastrigin function is studied. This function has several maximum and minimum points which have caused it to be utilize as a test function for assessment of the Meta-Heuristic Algorithms. So, the Rastrigin function is used for comparison of the evaluation and utility of COA algorithm.

$$f = 10n + \sum_{i=1}(x_i^2 - 10\cos(2\pi x_i)), \quad f(0,0,\ldots,0) = 0, \quad -5 \leq x_i \leq 5 \qquad \text{\_\_\_\_\_\_\_\_} \quad (10)$$

Rastrigin function is one of the difficult test functions and has plenty of local minimal, even in 3-dimensional case. Figure 3.20 shows the 3-dimensional Rastrigin function. The Rastrigin function is a really challenging optimization problem, as it is appear even in 3-dimensional case.

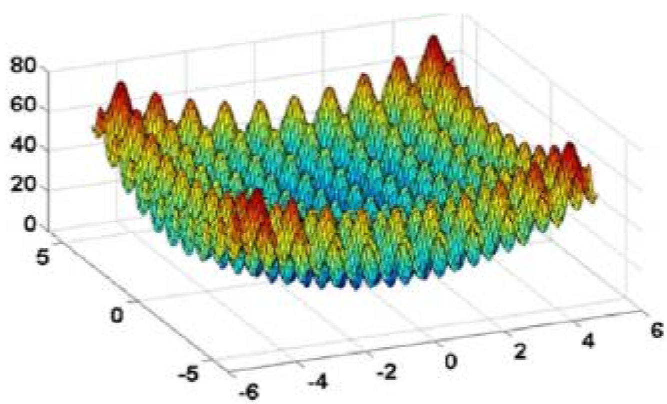


Figure 3.20 3D plot of Rastrigin function

The Meta-Heuristic algorithms are very sensitive for their parameters and the setting of the parameters can affect their efficiency. The parameters settings cause more reliability and flexibility of the algorithm. So, settings of the parameters are one of the crucial factors in gaining the optimized solution in all optimization problems. Table 3.2 shows the selected parameters for Cuckoo Optimization Algorithm (COA) algorithm.

Table 3.2 Parameters settings for COA algorithm

Maximum number of eggs	Minimum number of eggs	Number of initial population	Higher limitation of variable	Lower limitation of variable
4	2	5	30	-30
Population variance that cuts the optimization	**Control parameter of egg laying**	**Maximum number of cuckoos**	**Lambda variable**	**Number of clusters**
$1e^{-13}$	5	10	9	2

The results of Table 3.3 demonstrate that using the COA, Artificial Bee Colony (ABC) and Firefly Algorithm (FA) algorithm makes getting the optimized solution possible. The number of initial population is set 50 For ABC and FA algorithms and the number of iterations is set 100 for both algorithms. As can be seen, the COA algorithm reaches the optimum value. The results of the ABC and FA algorithms are derived from.

Table 3.3 Comparison of Results

Dimensional of Function	Range of search Space	ABC	FA	COA
2	±30	0.0059	0.1287	0
3	±30	0.0136	0.7516	0

To show the efficiency of COA, the convergence diagram is used. As shown in figure 3.21 – 3.26, the function of the algorithms in convergence toward the optimal solution in appropriate number of repetitions.

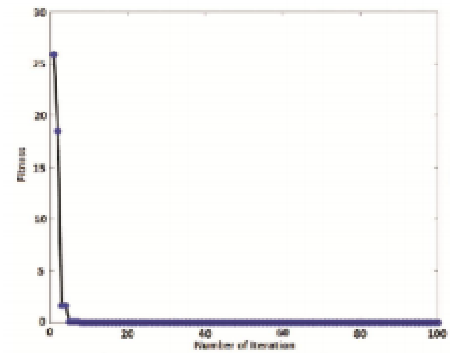


Figure 3.21 ABC for solving the two dimensional Rastrigin

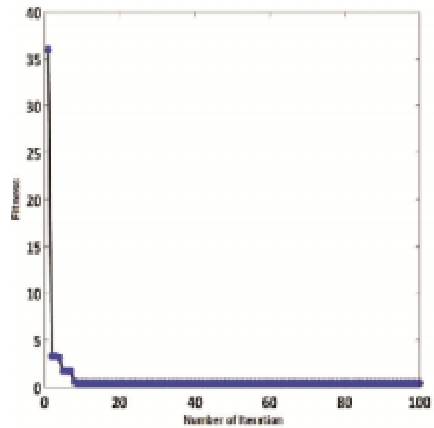


Figure 3.22 ABC for solving the three dimensional Rastrigin

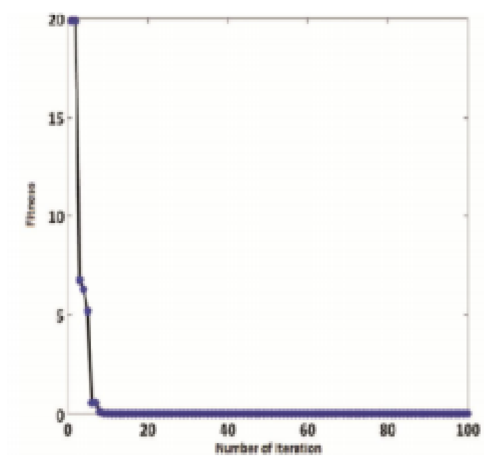


Figure 3.23 FA for solving the two dimensional Rastrigin

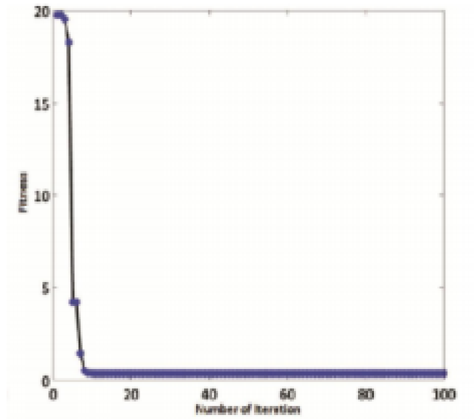


Figure 3.24 FA for solving the three dimensional Rastrigin

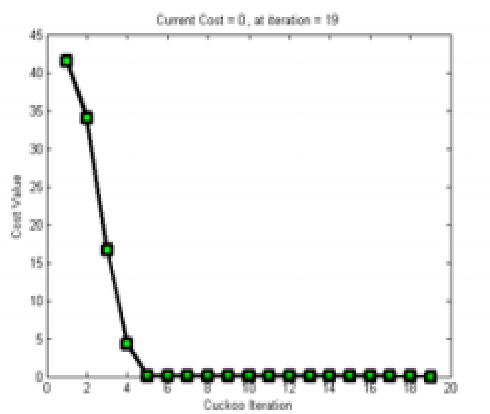


Figure 3.25 COA for solving the two dimensional Rastrigin

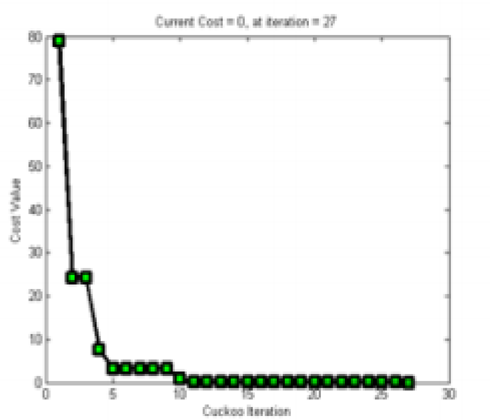


Figure 3.26 COA for solving the three dimensional Rastrigin

Table 3.4 shows the number of the repetition of the execution of COA, ABC and FA for two dimensional Rastrigin function. The results of table 3 and fig 5, show the fact that COA algorithm is more efficient in finding the global optimized points.

Table 3.4 The result of comparison for two dimensional Rastrigin function

Algorithm	Iteration				
	20	40	60	80	100
ABC	1.0372	1.1610	1.0056	0.0148	0.0059
FA	1.5273	1.3604	1.1312	1.0228	0.1287
COA	$4.26\ e^{-14}$	0	0	0	0

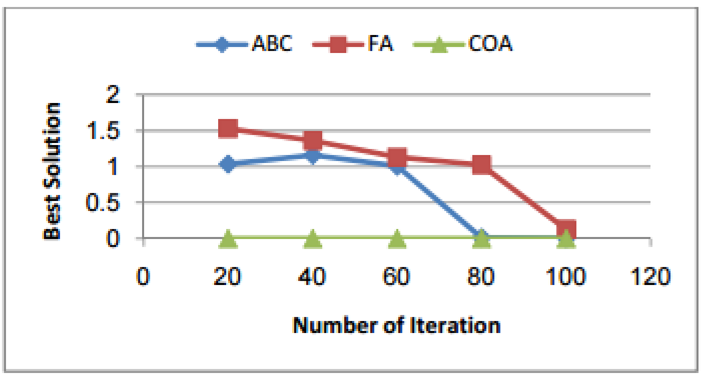


Figure 3.27 Comparison diagram for two dimensional Rastrigin function

Table 3.5 shows the repetition number of execution of COA, ABC and FA for three dimensional Rastrigin function. As it is seen, COA algorithm is more able in finding the global optimized points and is more efficient in solving the continuous optimization functions of large dimensions.

Table 3.5 The result of comparison for three dimensional Rastrigin function

Algorithm	Iteration				
	20	40	60	80	100
ABC	1.6723	1.1688	1.6165	0.0826	0.0136
FA	2.2512	2.1298	1.6228	1.1743	0.7516
COA	$7.01e^{-12}$	0	0	0	0

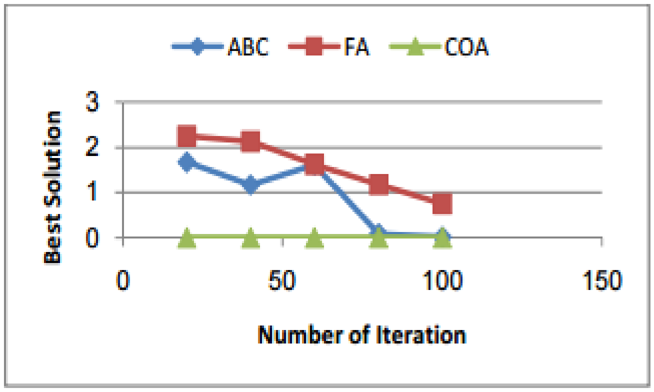


Figure 3.28 Comparison between algorithms for three dimensional Rastrigin function

By comparing both the algorithms and its performance evaluation COA algorithm is able to maintain the equilibrium of the local and global search of the problem in spite of the increase in the dimensions of it in an optimized way.

CHAPTER 4
SIMULATION OF THE PROPOSED SYSTEM

4.1 INTRODUCTION TO MATLAB

MATLAB is a software package for computation in engineering, science, and applied mathematics. It offers a powerful programming language, excellent graphics, and a wide range of expert knowledge. MATLAB is published by and a trademark of The MathWorks, Inc. The focus in MATLAB is on computation, not mathematics: Symbolic expressions and manipulations are not possible (except through the optional Symbolic Toolbox, a clever interface to maple). All results are not only numerical but inexact, thanks to the rounding errors inherent in computer arithmetic. The limitation to numerical computation can be seen as a drawback, but it's a source of strength too: MATLAB is much preferred to Maple, Mathematical, and the like when it comes to numerics.

On the other hand, compared to other numerically oriented languages like C++ and FORTRAN, MATLAB is much easier to use and comes with a huge standard library.1 the unfavorable comparison here is a gap in execution speed. This gap is not always as dramatic as popular lore has it, and it can often be narrowed or closed with good MATLAB programming (see section 6). Moreover, one can link other codes into MATLAB, or vice versa, and MATLAB now optionally supports parallel computing. Still, MATLAB is usually not the tool of choice for maximum-performance Computing.

The MATLAB niche is numerical computation on workstations for non-experts in computation. This is a huge niche—one way to tell is to look at the number of MATLAB-related books on mathworks.com. Even for supercomputer users, MATLAB can be a valuable environment in which to explore and fine-tune algorithms before more laborious coding in another language. Most successful computing languages and environments acquire a distinctive character or culture.

In MATLAB, that culture contains several elements: an experimental and graphical bias, resulting from the interactive environment and compression of the write-compile-link-execute analyze cycle; an emphasis on syntax that is compact and friendly to the interactive mode, rather than tightly constrained and verbose; a kitchen-sink mentality for providing functionality; and a high degree of openness and transparency (though not to the extent of being open source software).

4.1.1 GRAPHICAL VERSUS COMMAND-LINE USAGE

MATLAB was originally entirely a command-line environment, and it retains that orientation. But it is now possible to access a great deal of the functionality from graphical interfaces—menu's, buttons, and so on. These interfaces are especially useful to beginners, because they lay out the available choices clearly. As a rule, graphical interfaces can be more natural for certain types of interactive work, such as annotating a graph or debugging a program, whereas typed commands remain better for complex, precise, repeated, or reproducible tasks. One does not always need to make a choice, though; for instance, it is possible to save a figure's styles as a template that can be used with different data by pointing and clicking. Moreover, it can be able to do package code to distribute with our own graphical interface, one that itself may be designed with a combination of graphical and command-oriented tools. In the end, an advanced MATLAB user should be able to exploit both modes of work to be productive. That said, the focus of this document is on typed commands. In many cases these have graphical interface equivalents, even if I don't explicitly point them out. In particular, feel free to right-click (on Control-click on a Mac) on various objects to see what you might be able to do to them.

4.2 SIMULINK

Simulink (Simulation and Link) is an extension of MATLAB by Math works Inc. It works with MATLAB to offer modeling, simulating, and analyzing of dynamical systems under a graphical user interface (GUI) environment. The construction of a model is simplified with click-and-drag mouse operations. Simulink includes a comprehensive block library of toolboxes for both linear and nonlinear analyses. Models are hierarchical, which allow using both top-down and bottom-up approaches. As Simulink is an integral part of MATLAB, it is easy to switch back and forth during the analysis process and thus, the user may take full advantage of features offered in both environments.

4.3 DETAILED SPECIFICATIONS OF BLOCKS

4.3.1 WIND TURBINE

Nominal mechanical output power	:	1.5 W
Base wind speed	:	1.2 m/s
Maximum power at base wind speed	:	0.73 p.u
Base rotational speed	:	1.2 p.u
Pitch angle	:	0

4.3.2 ASYNCHRONOUS MACHINE

Rotor type	:`	Squirrel – cage
Nominal voltage (line to line) (V_n)	:	2400
Frequency	:	60 Hz
Preset Model	:	50 HP 460 V 60 HZ 760 RPM

4.3.3 THREE PHASE SERIES RLC LOAD

Nominal phase – phase voltage (V_n)	:	1000 V_{rms}
Nominal frequency (f_n)	:	50 HZ
Active power (P)	:	1000 W
Reactive Power	:	0 W

4.3.4 SWITCHES (DIODE) OF VIENNA RECTIFIER

Resistance (R_{on})	:	0.001 Ohms
Inductance (L_{on})	:	0 H
Forward voltage	:	0.8 V
Snubber resistance (R_s)	:	500 Ohms

4.3.5 SWITCHES OF INVERTER

FET Resistance (R_{on})	:	0.1 Ohms
Internal diode inductance	:	0 H
Internal diode resistance (R_d)	:	0.01 Ohms
Internal diode forward voltage	:	0 V

4.3.6 PHASE LOCKED LOOP

Minimum frequency	:	45 HZ
Initial frequency	:	60 HZ
Regulator gains [K_p, K_i, K_d]	:	180,3200,1

4.3 7 PID CONTROLLLER

Controller	:	PI
Time domain	:	Continuous time
Controller parameters :		
Proportional (P)	:	0.11
Integral (I)	:	0.1

4.3.8 PWM GENERATOR

Carrier frequency	:	2000 HZ
Modulation index	:	0.8
Output voltage frequency	:	60 HZ

Sample time : 0

4.3.9 PARALLEL RLC BRANCH

Branch type : R

Resistance (R) : 20 Ohms

4.4 SIMUALTION MODULE OF THE PROPOSED SYSTEM

Figure 4.1 shows the simulation module of the proposed system. Here Wind system and Concentrated Solar Power (CSP) plant is preferred as the input source for the system. The sub systems are shown in the following figures with simulation results.

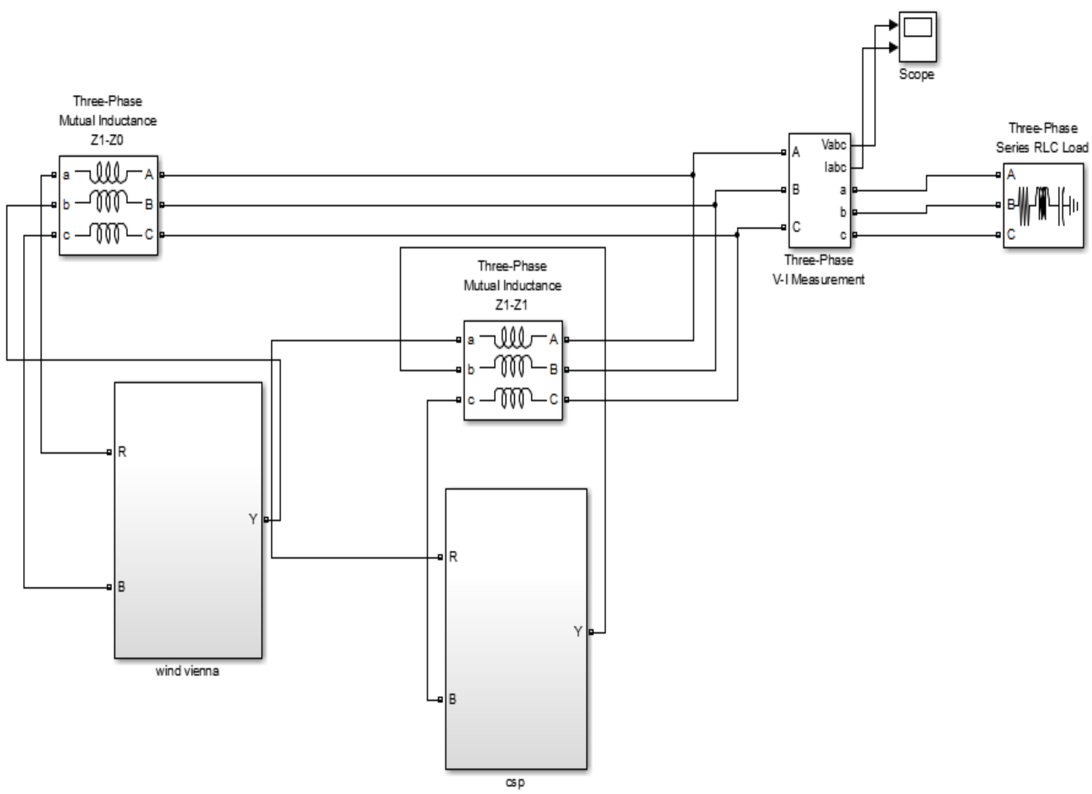


Figure 4.1 Simulink model of the proposed system

4.4.1 SIMULINK MODEL OF THE WIND SYSTEM

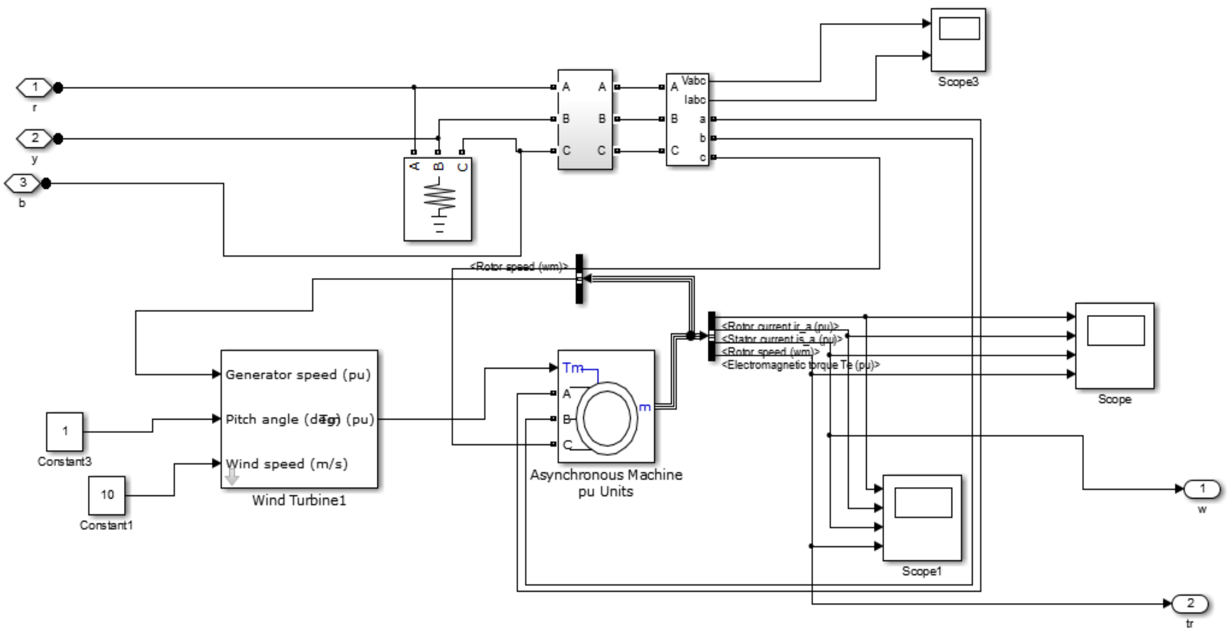


Figure 4.2 Simulink model of the wind subsystem

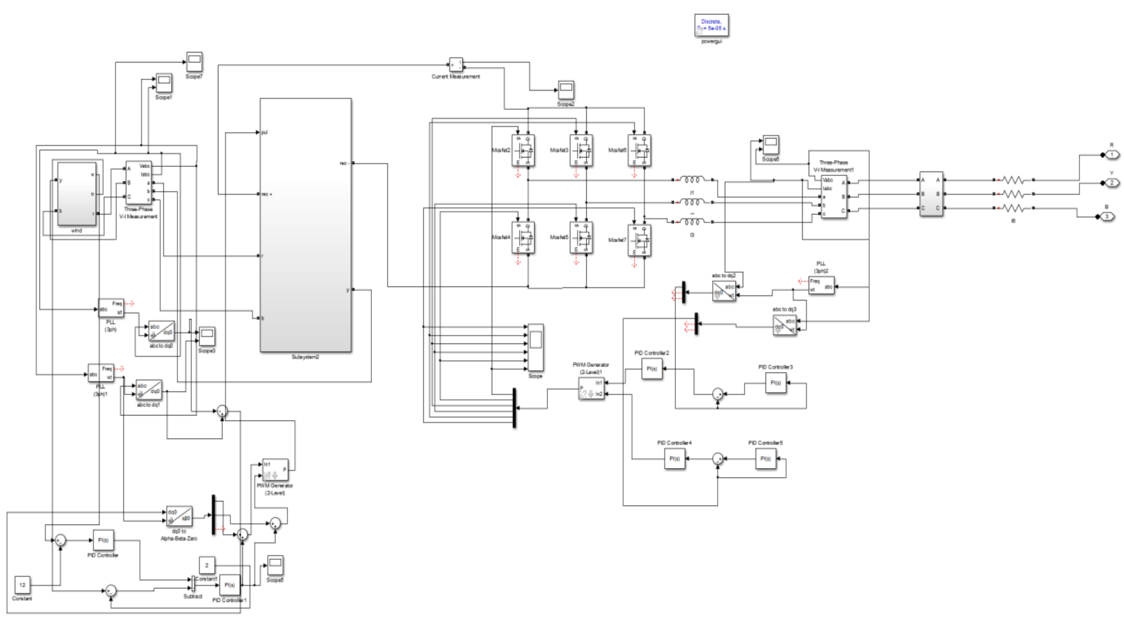


Figure 4.3 Simulink model of the wind turbine

Figure 4.2 shows the simulink model of Wind system. Here, Vienna rectifier is added to the wind system for reduce the switching losses and voltage stress on power semiconductor devices.

Here maximum power is tracked from the wind system using MPPT tracking. And accordingly the Vienna rectifier is operated. The Vienna rectifier simulation module is shown be in Figure 4.4.

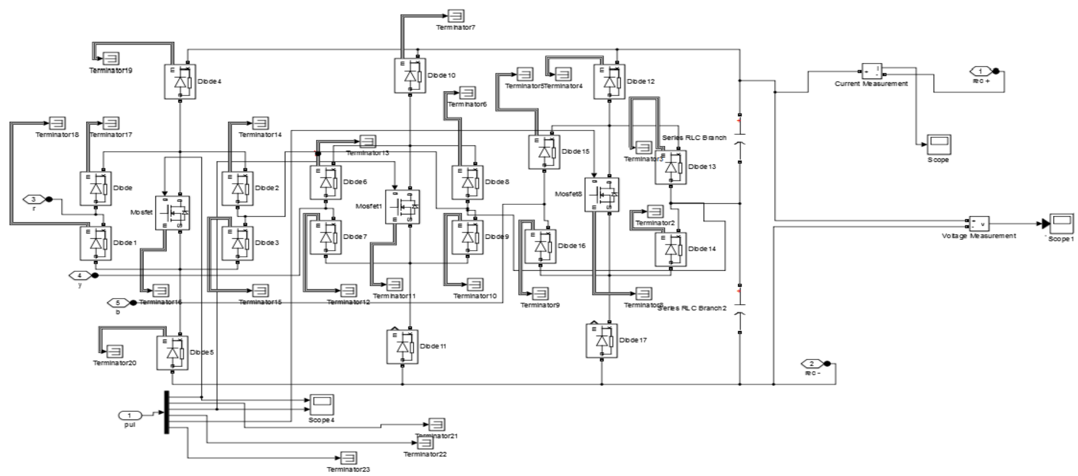


Figure 4.4 Simulink model of the Vienna rectifier

4.4.2 SIMULINK MODEL OF THE CSP SYSTEM

- The simulation module of the CSP sub system is shown in Figure 4.5. As discussed above this plant works on solar heat power.
- The heat energy from sunlight is collected by the receiver.
- The heat is pressurized to the extent by the hot tank.
- The turbine produces the energy and the energy is translated as voltage and current by the mask.
- A feedback is given to the cold tank which is again given to the receiver.

- The DC output is converted to AC by inverter.
- And switching pulses are applied to the PWM inverter.
- At final stage, the power is delivered to the loads

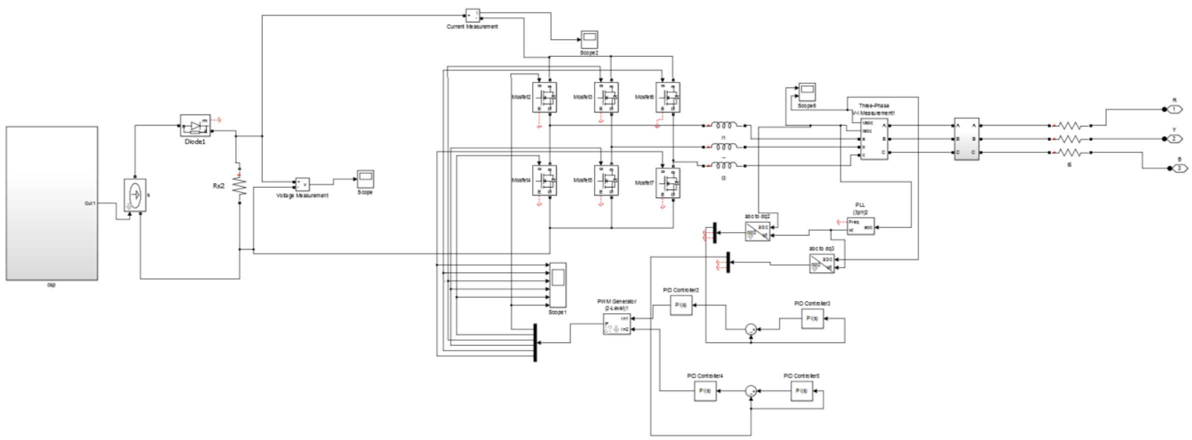


Figure 4.5 Simulink model of the concentrating solar power system

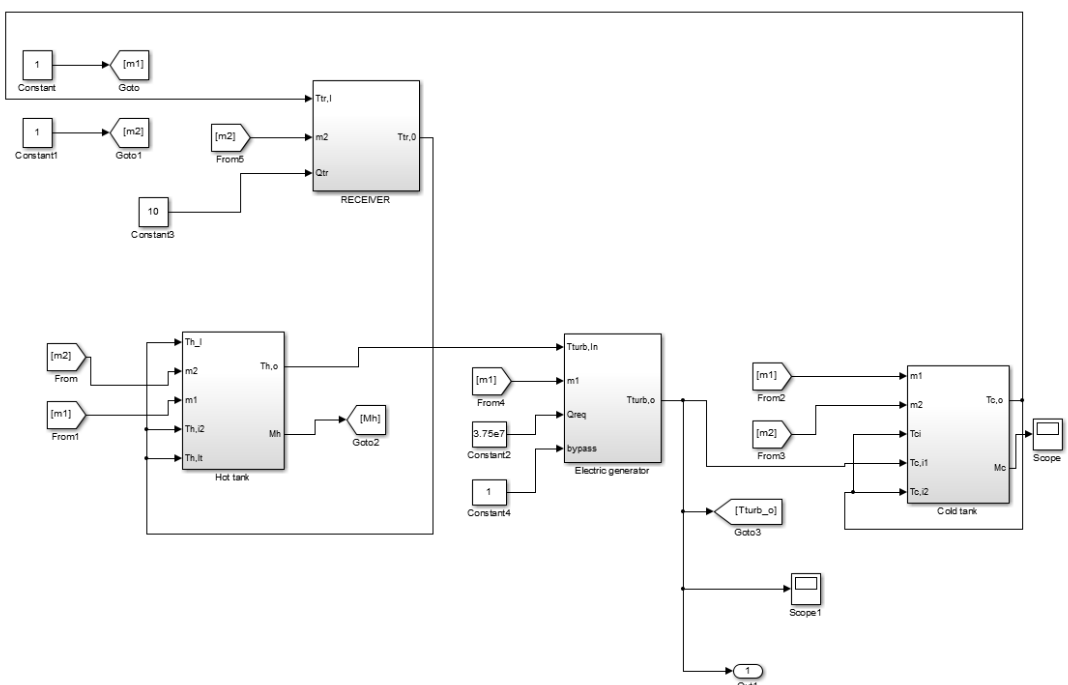


Figure 4.6 Simulink model of the CSP subsystem

4.4.3 CODING FOR ABC ALGORITHM

```
function abc(block)
y=0.1;
x=y;
clc;
clear;
close all;

%% Problem Definition

CostFunction=@(x) Sphere(x);        % Cost Function
nVar=5;             % Number of Decision Variables
VarSize=[1 nVar];   % Decision Variables Matrix Size
VarMin=-10;         % Decision Variables Lower Bound
VarMax= 10;         % Decision Variables Upper Bound

%% ABC Settings

MaxIt=200;              % Maximum Number of Iterations

nPop=100;               % Population Size (Colony Size)

nOnlooker=nPop;         % Number of Onlooker Bees

L=round(0.6*nVar*nPop); % Abandonment Limit Parameter (Trial Limit)

a=1;                    % Acceleration Coefficient Upper Bound

%% Initialization

% Empty Bee Structure
empty_bee.Position=[];
empty_bee.Cost=[];


% Initialize Population Array
pop=repmat(empty_bee,nPop,1);


% Initialize Best Solution Ever Found
BestSol.Cost=inf;


% Create Initial Population
```

```
for i=1:nPop
    pop(i).Position=unifrnd(VarMin,VarMax,VarSize);
    pop(i).Cost=CostFunction(pop(i).Position);
    if pop(i).Cost<=BestSol.Cost
    BestSol=pop(i);
    end
end

% Abandonment Counter
C=zeros(nPop,1);

% Array to Hold Best Cost Values
BestCost=zeros(MaxIt,1);

%% ABC Main Loop

for it=1:MaxIt

    % Recruited Bees
    for i=1:nPop

        % Choose k randomly, not equal to i
        K=[1:i-1 i+1:nPop];
        k=K(randi([1 numel(K)]));


        % Define Acceleration Coeff.
        phi=a*unifrnd(-1,+1,VarSize);

        % New Bee Position
        newbee.Position=pop(i).Position+phi.*(pop(i).Position-
pop(k).Position);

        % Evaluation
        newbee.Cost=CostFunction(newbee.Position);

        % Comparision
        if newbee.Cost<=pop(i).Cost
            pop(i)=newbee;
        else
```

```
            C(i)=C(i)+1;
        end
    end

    % Calculate Fitness Values and Selection Probabilities
    F=zeros(nPop,1);
    MeanCost = mean([pop.Cost]);
    for i=1:nPop
        F(i) = exp(-pop(i).Cost/MeanCost); % Convert Cost to Fitness
    end
    P=F/sum(F);

    % Onlooker Bees
    for m=1:nOnlooker

        % Select Source Site
        i=RouletteWheelSelection(P);

        % Choose k randomly, not equal to i
        K=[1:i-1 i+1:nPop];
        k=K(randi([1 numel(K)]));

        % Define Acceleration Coeff.
        phi=a*unifrnd(-1,+1,VarSize);

        % New Bee Position
        newbee.Position=pop(i).Position+phi.*(pop(i).Position-
pop(k).Position);

        % Evaluation
        newbee.Cost=CostFunction(newbee.Position);

        % Comparision
        if newbee.Cost<=pop(i).Cost
            pop(i)=newbee;
        else
            C(i)=C(i)+1;
        end
```

4.4.4 CODING FOR CUCKOO ALGORITHM

```
function abc(block)
y=0.1;
x=y;
clc;
clear;
close all;
clc, clear, close all

%% Set problem parameters
% select your cost function:
costFunction = 'rastrigin';           % F6 +/-5.12

npar  = 100;          % number of optimization variables
varLo = -5;          % Lower  band of parameter
varHi =  5;          % Higher band of parameter

%% Set COA parameters

numCuckooS = 5;              % number of initial population
minNumberOfEggs = 2;         % minimum number of eggs for each cuckoo
maxNumberOfEggs = 4;         % maximum number of eggs for each cuckoo
maxIter = 100;               % maximum iterations of the Cuckoo Algorithm
knnClusterNum = 1;           % number of clusters that we want to make
motionCoeff = 9;             % Lambda variable in COA paper, default=2
accuracy = -inf;            % How much accuracy in answer is needed
maxNumOfCuckoos = 10;       % maximum number of cuckoos that can live at the
same time
radiusCoeff = 5;            % Control parameter of egg laying
cuckooPopVariance = 1e-13;   % population variance that cuts the optimization

%% initialize population:

cuckooPop = cell(numCuckooS,1);
% initialize egg laying center for each cuckoo
for cuckooNumber = 1:numCuckooS
    cuckooPop{cuckooNumber}.center = ( varHi-varLo )*rand(1,npar) + varLo;
```

```
end

%% initialize COA cost minimization plot
figure(1)
hold on
xlabel 'Cuckoo iteration'
ylabel 'Cost Value'

%% Start Cuckoo Optimization Algorithm

iteration = 0;
maxProfit = -1e20;         % Let initial value be negative number
goalPoint = (varHi - varLo)*rand(1,npar) + varLo; % a random goalpoint to
start COA
globalBestCuckoo = goalPoint;
globalMaxProfit = maxProfit;
profitVector = [];
while ( (iteration <= maxIter) && (-maxProfit > accuracy) )

    iteration = iteration + 1

    % initialize number of eggs for each cuckoo
    for cuckooNumber = 1:numCuckooS
        cuckooPop{cuckooNumber}.numberOfEggs = floor( (maxNumberOfEggs -
minNumberOfEggs) * rand + minNumberOfEggs );
    end
    % get total number of available eggs between all cuckooS
    summ = 0;
    for cuckooNumber = 1:numCuckooS
        summ = summ + cuckooPop{cuckooNumber}.numberOfEggs;
    end
    % calculate egg laying radius for each Cuckoo, considering problem
    % limitations and ratio of each cuckoo's eggs
    for cuckooNumber = 1:numCuckooS
        cuckooPop{cuckooNumber}.eggLayingRadius =
cuckooPop{cuckooNumber}.numberOfEggs/summ * ( radiusCoeff * (varHi-varLo) );
    end
```

```
    % To lay eggs, we produced some radius values less than egg laying
    % radius of each cuckoo
    for cuckooNumber = 1:numCuckooS
        cuckooPop{cuckooNumber}.eggLayingRadiuses =
cuckooPop{cuckooNumber}.eggLayingRadius *
rand(cuckooPop{cuckooNumber}.numberOfEggs,1);
    end

    for cuckooNumber = 1:numCuckooS
        params = cuckooPop{cuckooNumber}.center;        % get center values
        tmpRadiuses = cuckooPop{cuckooNumber}.eggLayingRadiuses;
        numRadiuses = numel(tmpRadiuses);
        % divide a (hyper)circle to 'numRadiuses' segments
        % This is to search all over the current habitat
        angles = linspace(0,2*pi,numRadiuses);    % in Radians
        newParams = [];
        for cnt = 1:numRadiuses
            addingValue = zeros(1,npar);
            for iii = 1:npar
                randNum = floor(2*rand)+1;
                addingValue(iii) = (-1)^randNum *
tmpRadiuses(cnt)*cos(angles(cnt)) + tmpRadiuses(cnt)*sin(angles(cnt));
            end
            newParams = [newParams; params +  addingValue ];
        end

        % check for variable limits
        newParams(find(newParams>varHi)) = varHi;
        newParams(find(newParams<varLo)) = varLo;

        cuckooPop{cuckooNumber}.newPosition4Egg = newParams;
    end

    % Now egg laying is done
```

```
    % Now that egg positions are found, they are laid, and so its time to
    % remove the eggs on the same positions (because each egg only can go to
one nest)
    for cuckooNumber = 1:numCuckooS
        tmpPopulation = cuckooPop{cuckooNumber}.newPosition4Egg;
        tmpPopulation = floor(tmpPopulation * 1e20)/1e20;
        ii = 2;
        cntt = 1;
        while ii <= size(tmpPopulation,1) || cntt <= size(tmpPopulation,1)
            if all((tmpPopulation(cntt,:) == tmpPopulation(ii,:)))
                tmpPopulation(ii,:) = [];
            end
            ii = ii + 1;
            if ii > size(tmpPopulation,1) && cntt <= size(tmpPopulation,1)
                cntt = cntt + 1;
                ii = cntt + 1;
                if ii > size(tmpPopulation,1)
                    break
                end
            end
        end
        cuckooPop{cuckooNumber}.newPosition4Egg = tmpPopulation;
    end


    % Now we evalute egg positions
    for cuckooNumber = 1:numCuckooS
        cuckooPop{cuckooNumber}.profitValues = -
feval(costFunction,[cuckooPop{cuckooNumber}.center ;
cuckooPop{cuckooNumber}.newPosition4Egg]);
    end

    % Now we check to see if cuckoo population is more than maxNumOfCuckoos
    % this case we should keep 1st maxNumOfCuckoos cuckoos and kill the
others
    allPositions = [];
    whichCuckooPopTheEggBelongs = [];
```

```
    tmpProfits = [];
    if numCuckooS > maxNumOfCuckoos
        for cuckooNumber = 1:numCuckooS
            tmpProfits = [tmpProfits; cuckooPop{cuckooNumber}.profitValues];
            allPositions = [allPositions; [cuckooPop{cuckooNumber}.center;
cuckooPop{cuckooNumber}.newPosition4Egg(:,1:npar)]];
            whichCuckooPopTheEggBelongs = [whichCuckooPopTheEggBelongs;
cuckooNumber*ones(size(cuckooPop{cuckooNumber}.newPosition4Egg(:,1:npar),1),1
) ];
        end
        % now we sort cuckoo profits
        [sortedProfits, sortingIndex] = sort(tmpProfits,'descend');
        % Get best cuckoo to be copied to next generation
        bestCuckooCenter = allPositions(sortingIndex(1),1:npar);

        sortedProfits = sortedProfits(1:maxNumOfCuckoos);
        allPositions = allPositions(sortingIndex(1:maxNumOfCuckoos),:);
        clear cuckooPop
        for ii = 1:maxNumOfCuckoos
            cuckooPop{ii}.newPosition4Egg = allPositions(ii,:);
            cuckooPop{ii}.center = allPositions(ii,:);
            cuckooPop{ii}.profitValues = sortedProfits(ii);
        end
        numCuckooS = maxNumOfCuckoos;
    else
        for cuckooNumber = 1:numCuckooS
            tmpProfits = [tmpProfits; cuckooPop{cuckooNumber}.profitValues];
            allPositions = [allPositions; [cuckooPop{cuckooNumber}.center;
cuckooPop{cuckooNumber}.newPosition4Egg(:,1:npar)] ];
            whichCuckooPopTheEggBelongs = [whichCuckooPopTheEggBelongs;
cuckooNumber*ones(size(cuckooPop{cuckooNumber}.newPosition4Egg(:,1:npar),1),1
) ];
        end
        [sortedProfits, sortingIndex] = sort(tmpProfits,'descend');
        % Get best cuckoo to be copied to next generation
        bestCuckooCenter = allPositions(sortingIndex(1),1:npar);
    end
```

```
    maxProfit  = sortedProfits(1);
    currentBestCuckoo = bestCuckooCenter;
    currentMaxProfit = -feval(costFunction,currentBestCuckoo);
    if currentMaxProfit > globalMaxProfit
        globalBestCuckoo = currentBestCuckoo;
        globalMaxProfit = currentMaxProfit;
    end

    % Update cost minimization plot
    plot(iteration, -
globalMaxProfit,'ks','linewidth',2,'MarkerEdgeColor','k','MarkerFaceColor','g
','MarkerSize',10)
    title([ 'Curent Cost = ' num2str(-globalMaxProfit) ' , at Iteration = '
num2str(iteration) ])
    pause(0.01)

    profitVector = [profitVector globalMaxProfit];

    allPositions = [];
    whichCuckooPopTheEggBelongs = [];
    for cuckooNumber = 1:numCuckooS
        allPositions = [allPositions;
cuckooPop{cuckooNumber}.newPosition4Egg(:,1:npar)];
```

CHAPTER 5

SIMULATION RESULTS

5.1 WIND SYSTEM OUTPUT VOLTAGE AND CURRENT

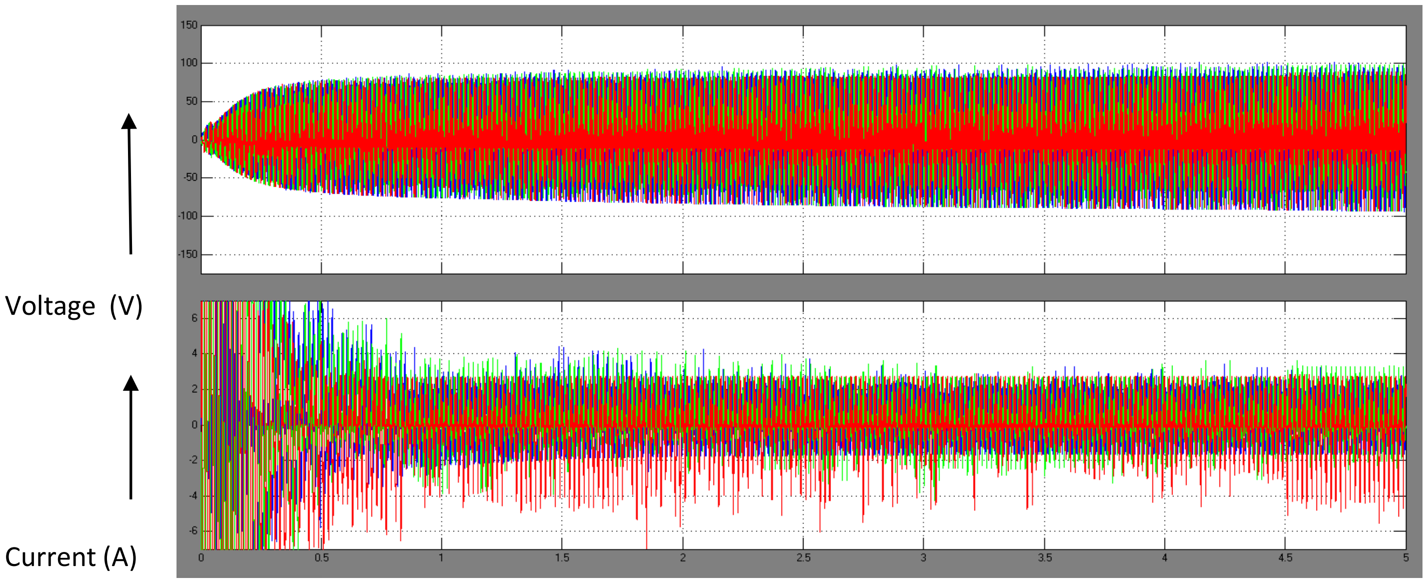


Figure 5.1 Output of wind system

5.2 OUTPUT VOLTAGE AND CURRENT WAVEFORMS WITH VIENNA RECTIFIER

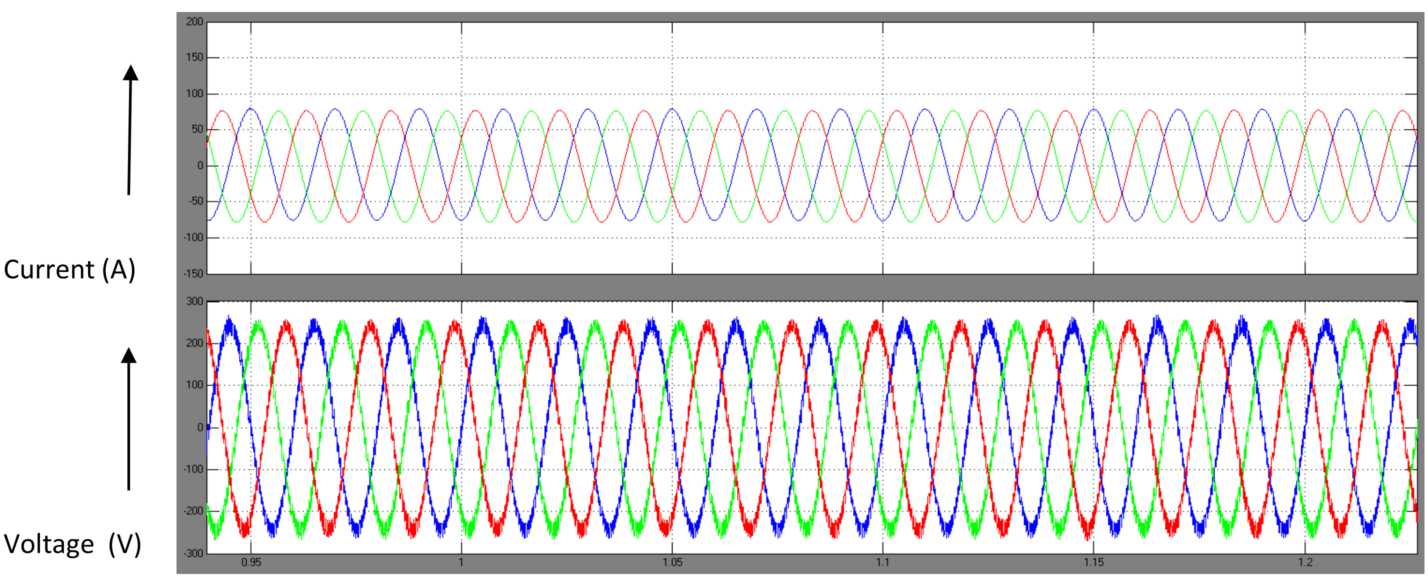


Figure 5.2 Output of Vienna rectifier

5.3 VIENNA RECTIFIER DC VOLTAGE

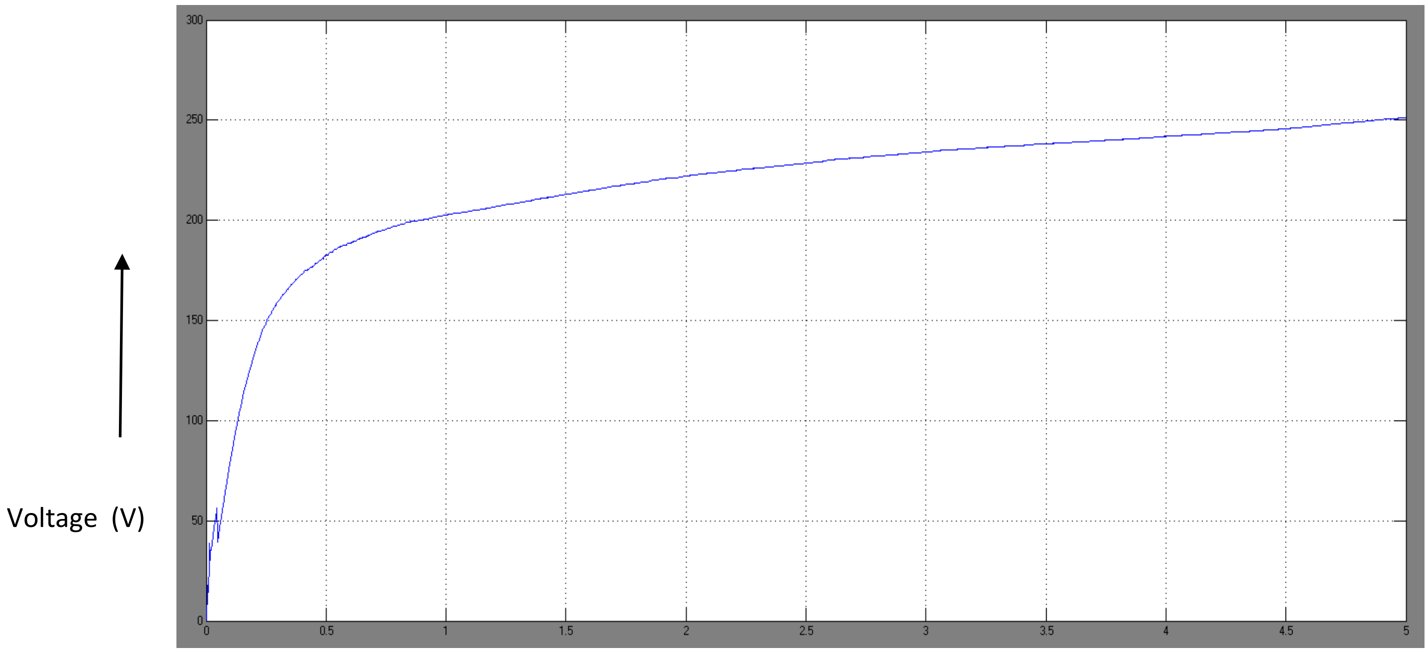


Figure 5.3 Output voltage of Vienna rectifier

5.4 CSP OUTPUT VOLTAGE AND CURRENT WAVEFORMS

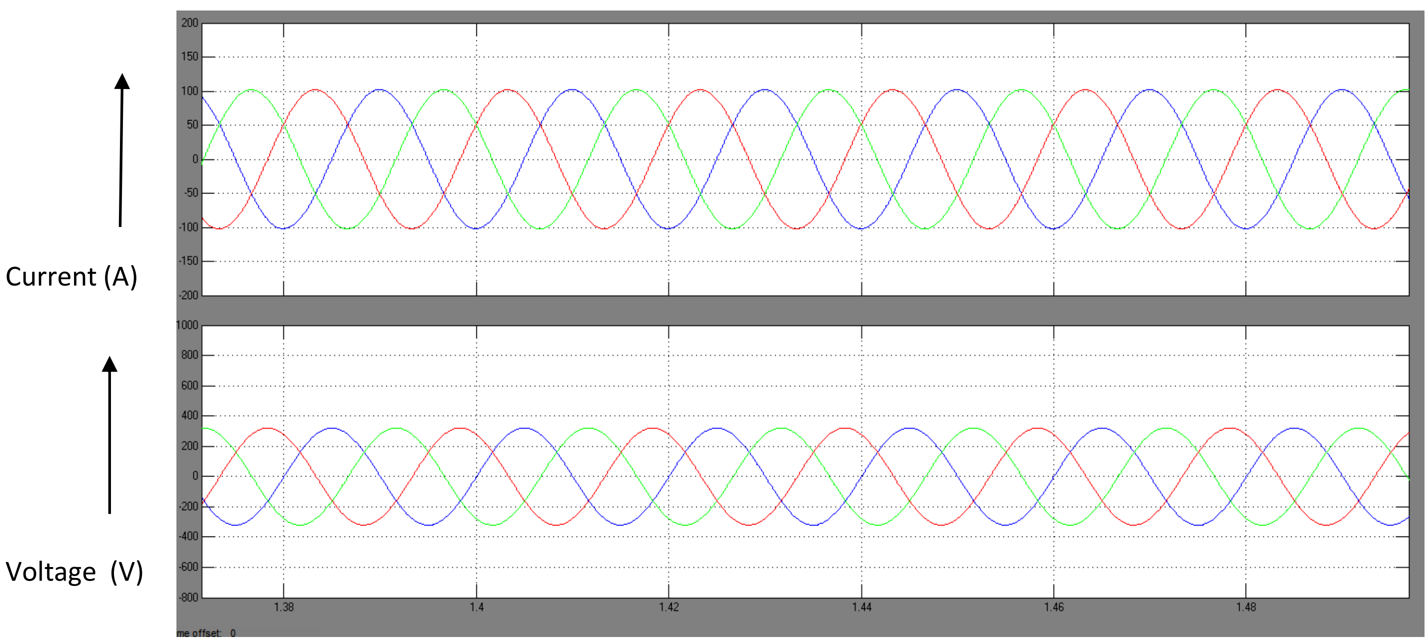


Figure 5.4 Output of concentrating solar power system

5.5 OUTPUT VOLTAGE AND CURRENT WAVEFORMS OF PROPOSED SYSTEM

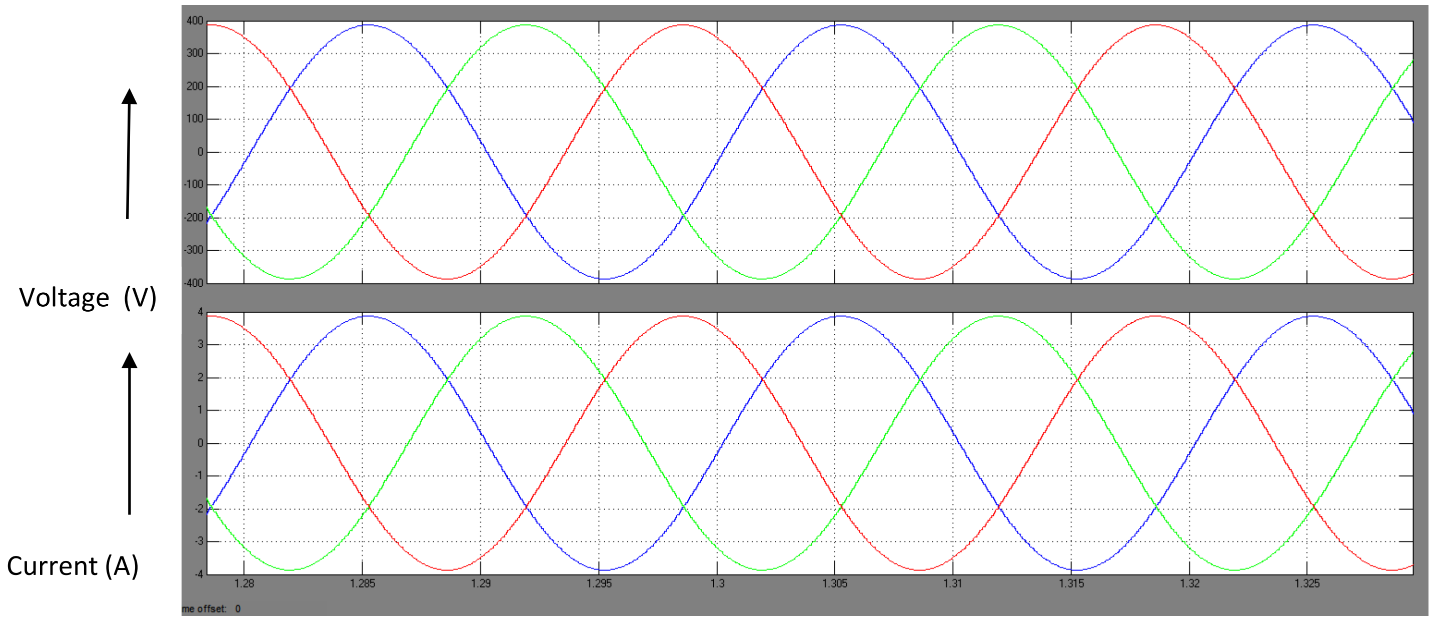


Figure 5.5 Output of the proposed system

5.6 CSP WITH ABC ALGORITHM

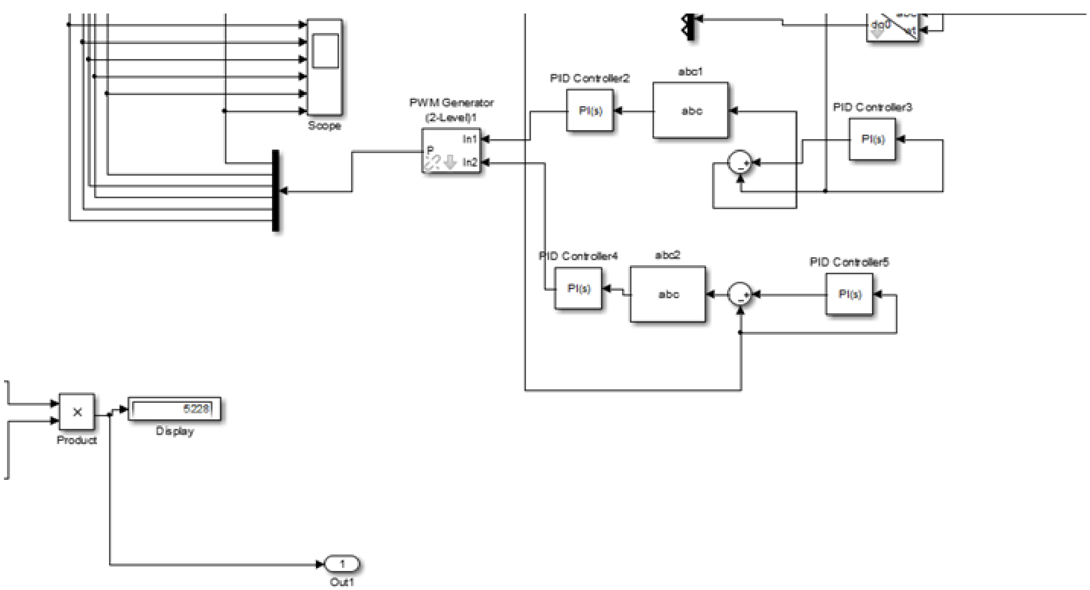


Figure 5.6 CSP system with ABC algorithm

5.7 OUTPUT VOLTAGE AND CURRENT WAVEFORMS WITH ABC ALGORITHM

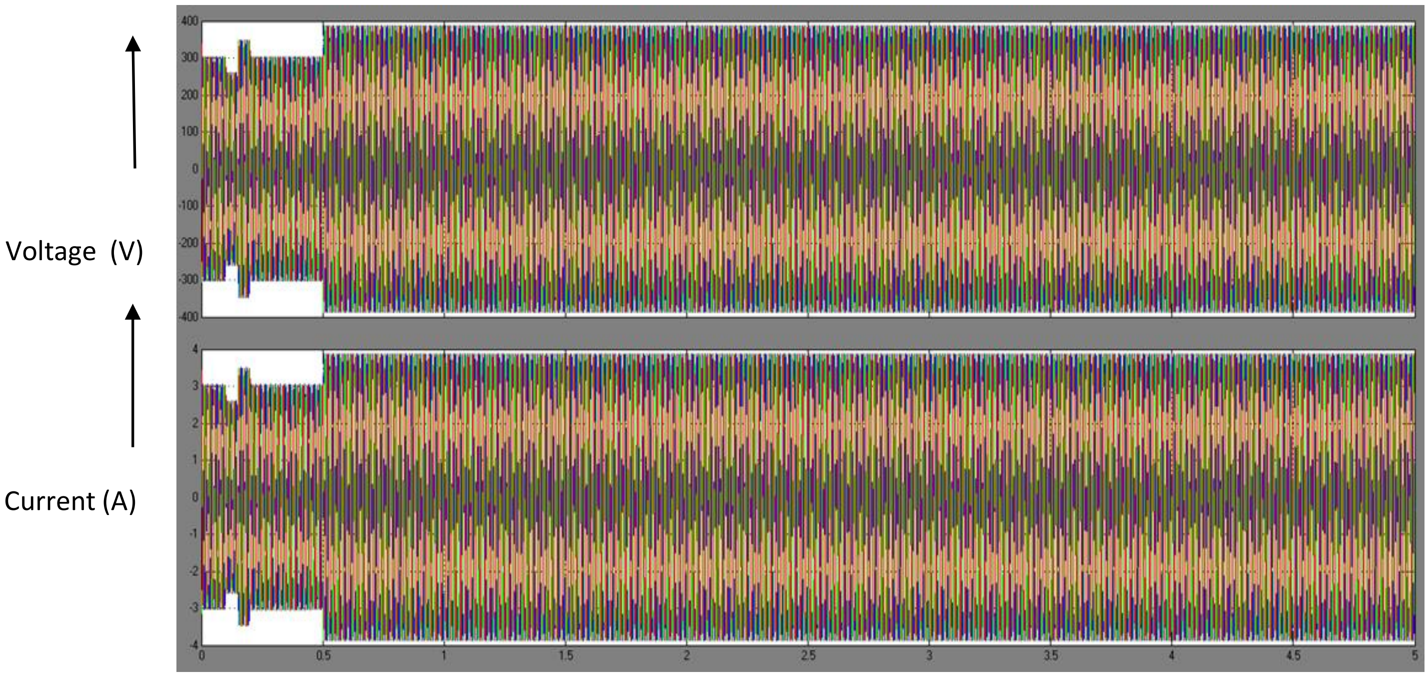


Figure 5.7 Output voltage and current with ABC algorithm

5.8 OUTPUT EFFICIENCY AND POWER DISPLAY FOR ABC ALGORITHM

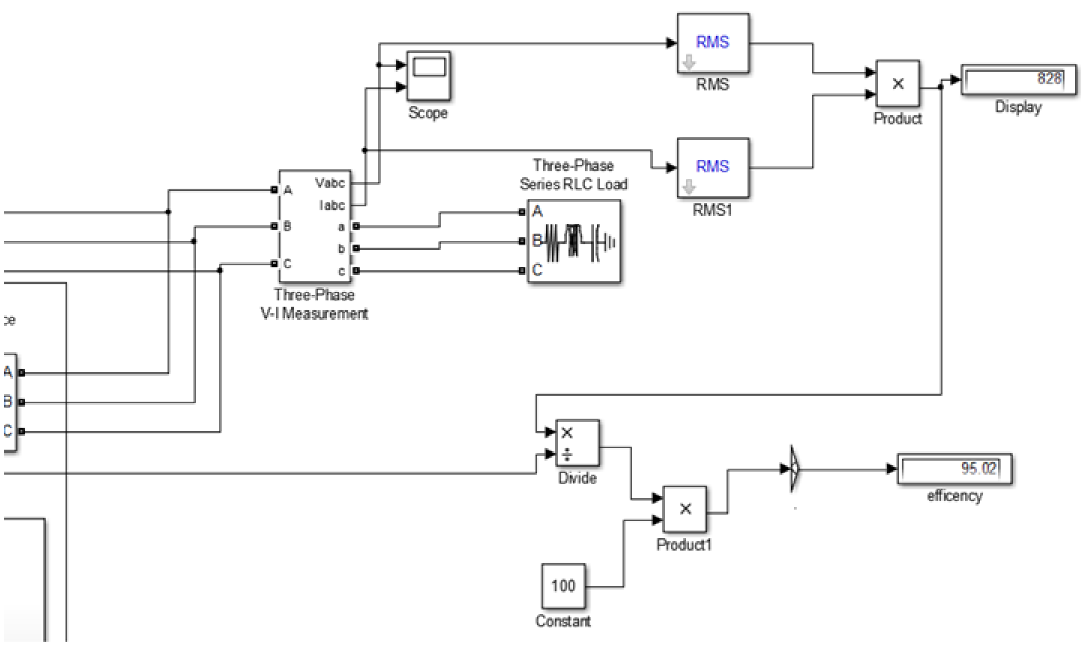


Figure 5.8 Output efficiency and power display for abc algorithm

5.9 PROPOSED CUCKOO ALGORITHM FOR CSP SYSTEM

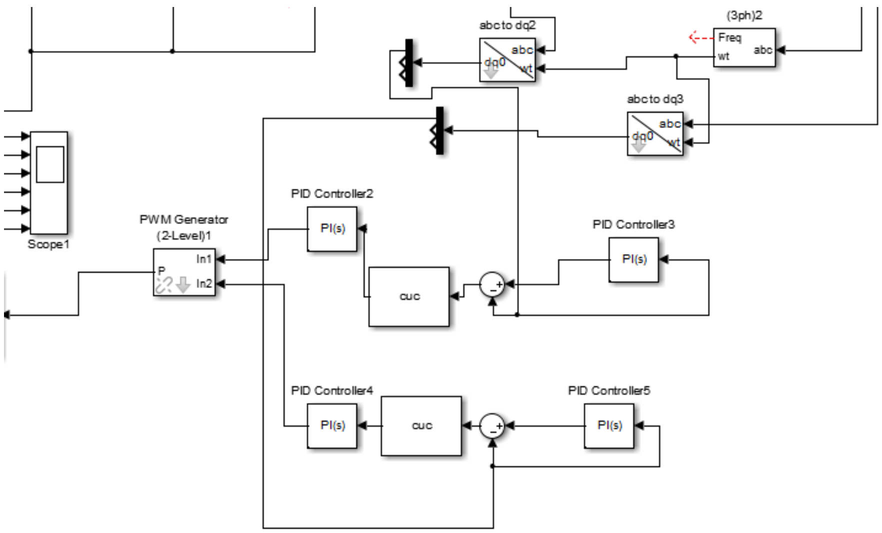


Figure 5.9 Proposed cuckoo algorithm for CSP system

5.10 OUTPUT VOLTAGE AND CURRENT WAVEFORM WITH CUCKOO SEARCH

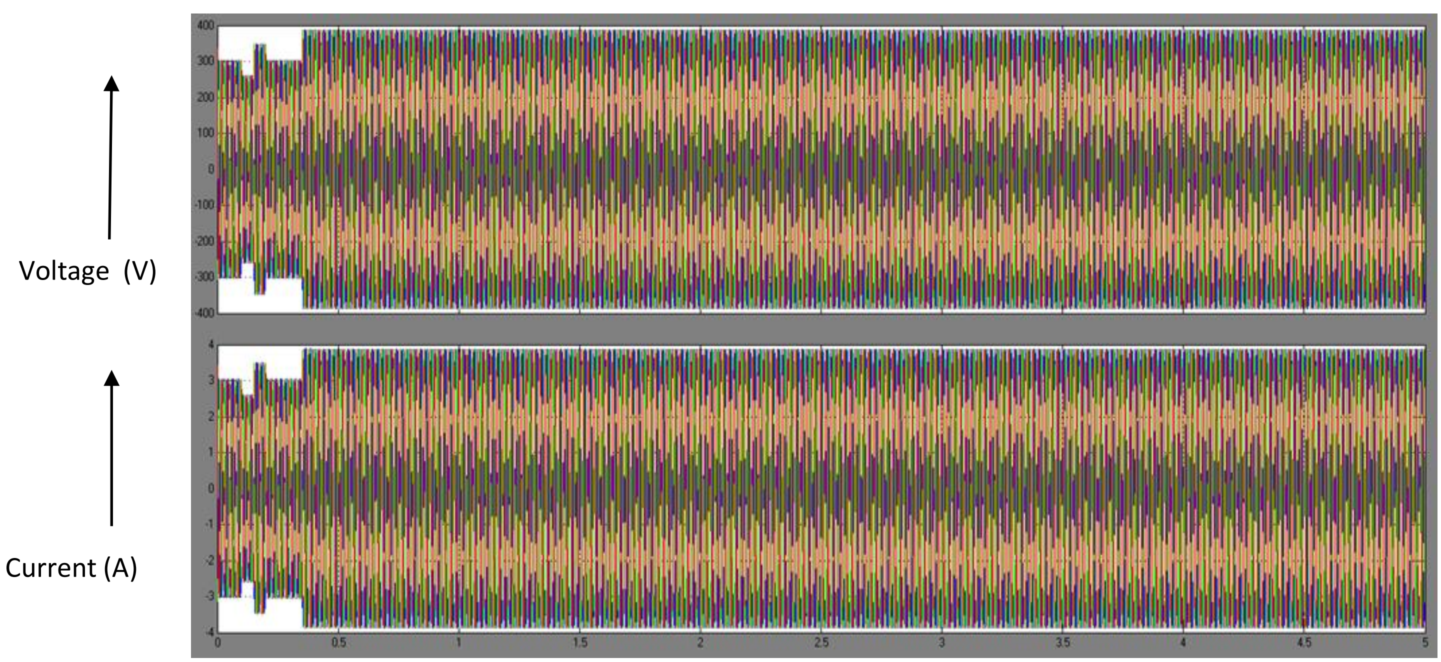


Figure 5.10 Output voltage and current with cuckoo search algorithm

5.11 OUTPUT EFFICIENCY AND POWER DISPLAY FOR CUCKOO SEARCH

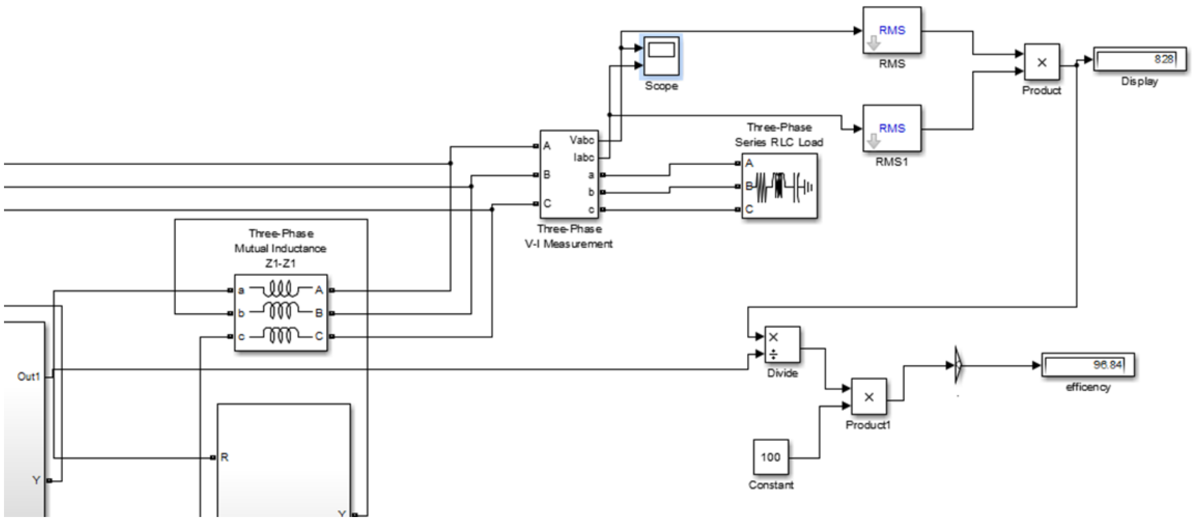


Figure 5.11 Output efficiency and power display for cuckoo search algorithm

5.12 VOLTAGE AND CURRENT VALUES

Wind system voltage	:	70 V
Wind system current	:	6 A
Vienna rectifier DC voltage	:	250 V
Output voltage with Vienna rectifier	:	230 V
Output current with Vienna rectifier	:	60 A
Output voltage of CSP	:	320 V
Output current of CSP	:	80 A
Output voltage of proposed system	:	400 V
Output current of proposed system	:	4 A

5.12 COMPARISON BETWEEN ABC AND CUCKOO SEARCH ALGORITHM

Algorithms	Output Power (W)	Efficiency
ABC	828	95.02
CUCKOO Search	828	96.84

- In the proposed system Cuckoo optimization algorithm and ABC algorithm is used to solve the problems. In Cuckoo optimization algorithm, the stability of the system is attained in fast time period.
- The output efficiency of the system is highly improved in the proposed cuckoo method compared to the other conventional method.

CHAPTER 6
CONCLUSION

In the proposed system the efficiency of the conventional system has been improved by using Vienna rectifier in the wind system. Here maximum losses such as core losses, iron losses are reduced because of the absence of transformer. The power quality problems incurred in the system has been optimized and the efficiency is still improved by using cuckoo optimization algorithm. The benefits and comparison of COA with other optimization techniques are analyzed and presented in details. When compared to the conventional algorithm technique the iteration steps are much reduced here and the stability is attained in short period of time. The efficiency and the stability of the system are verified by simulating the proposed system by using MATLAB Simulink. The proposed system is a promising alternative in locations where the extension of the electrical grid is difficult or not economical and the cost of electricity is high.

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