PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

Ministry of Higher Education and Scientific Research

University of Amar Telidji - Laghouat

Faculty of Technology

Department of Electrical Engineering

Option: Power Systems

Realized by

Mennad Khaoula / Taibi Khedidja

THEME

SOLVING ECONOMIC DISPATCH PROBLEM IN SMART GRID

Nom et Prénom	**Grade**	**Quality**
LAHDEB Mohammed	MCA	Chair
CHETTIH Saliha	Prof	Supervisor
ARIF Salem	Prof	Examine
BENTOUATI Bachir	Doctor	Co-supervisor

2021/2022

République Algérienne Démocratique et Populaire

Ministère de l'Enseignement Supérieur et de la Recherche Scientifique

Université Amar Telidji- Laghouat

FACULTE : Technologie

DEPARTEMENT : Electrotechnique

Option : réseau électrique

Réalise par :

Mennad khaoula / Taibi khedidja

Thème

Résolution du Problème de la Répartition Économique des Puissances dans un Réseau Électrique Intelligent

Nom et Prénom	**Grade**	**Qualité**
LAHDEB Mohammed	Prof	Président
ARIF Salem	Prof	Examinateur
CHETTIH Saliha	Prof	Rapporteur
BENTTOUATI Bachir	Doctor	Co-Rapporteur

2021/2022

Dedication

I dedicate my dissertation work to my loving parents Mohammed and yamina , my brothers ayoub , attalah and youcef who have supported me throughout the process.

I dedicate to my friend Khaoula mennad who has always been by my side to finish this work despite all the problems.

thank you very much ; Love you all

Khedidja

Dedication

To whom Allah - Glory be to Him - has placed Paradise under her feet, and venerated in His Mighty Book my dear mother

Ms. karboun Fatma

To the one who is the best example for the head of the family, who never hesitated to open the path of good and happiness. To my esteemed father

Mr Abd El Kader

On whom I rely in every big and small, my brother: Islem, and sisters: Meriem and Amina

To everyone who did not hesitate to extend a helping hand to me, especially my right hand,

Khedidja taibi

I dedicate my humble work to you

Khaoula

Acknowledgements

Tanks to almighty ALLAH for giving me the strength and the ability to understand and complete this work

Foremost, we would like to thank our supervisor Professor CHETTIH Saliha and our co-supervisor doctor BENTOUATI Bachir for their supervision of this dissertation and especially for their scientific and human qualities.

I would also like to thank the honorable thesis committee Prof. LAHDEB Mohammed, Prof. ARIF Salem for accepting to evaluate this work.

We also thank all our colleagues for their moral support throughout the course.

ملخص

الشبكة الذكية هي مفتاح الاستخدام المفيد والعقلاني لمصادر الطاقة، مهما كان نوعها وطبيعتها. تستخدم تكنولوجيا المعلومات والاتصالات الرقمية وكذلك الطاقات المتجددة. إنه مجال بحثي في حد ذاته بسبب حرارته وتوافره وطبيعته الصديقة للبيئة. يمثل هذا الاندماج بين الشبكات الذكية والطاقات المتجددة تحديًا على المستوى الاقتصادي والطاقة للدول التي تتبنى هذا الاندماج، وفي مشروعنا نحاول دراسة تأثير مساهمة طاقة الرياح في تقليل التكلفة الإجمالية وعلى التوزيع الجيد. من الطاقة وإرضاء جميع المستهلكين من حيث الجودة والوفرة باستخدام طريقة GWO من أجل حل مشاكل التوزيع الاقتصادي المتمثلة بالقيود لضمان أفضل وأقل تكلفة ممكنة

Abstract

The smart grid is the key to the useful and rational use of energy sources, whatever their type and nature. It uses digital information and communication technology as well as renewable energies. It is an area of research in itself due to its heat, availability and eco-friendly nature. This fusion between smart grids and renewable energies presents a challenge at the economic and energy level for the countries that adopt this fusion, and in our project, we are trying to study the impact of the contribution of wind energy in reducing the overall cost and on good distribution. of energy and satisfy all consumers in terms of quality and abundance using the gwo method in order to solve the problems of economic distribution of constraints to ensure the best and lowest possible cost

Résumé

Le réseau intelligent est la clé de l'utilisation utile et rationnelle des sources d'énergie, quels que soient leur type et leur nature. Il utilise les technologies numériques de l'information et de la communication ainsi que les énergies renouvelables. C'est un domaine de recherche de sa disponibilité et de son caractère écologique. Cette fusion entre smart grids et énergies renouvelables présente un défi au niveau économique et énergétique pour les pays qui adoptent cette fusion, et dans notre projet nous essayons d'étudier l'impact de l'apport de l'énergie éolienne dans la réduction du coût global et sur la bonne Distribution. d'énergie et satisfaire tous les consommateurs en termes de qualité et d'abondance en utilisant la méthode gwo afin de résoudre les problèmes de répartition économique des contraintes pour assurer le meilleur et le plus bas coût possible

Table of Contents

Chapter II : Optimization Method

Chapter III: Simulation results

List of Figures

List of Tables

Abbreviation:

EDP: economic dispatch problem

GA: Genetic Algorithm

ACO: Ant Colony Optimization

PSO: Particle Swarm Optimizer

GWO: grey wolf optimizer

SG: smart grid

RES: renewable energies

SGAM: smart grids architecture model

DER: distributed energy sources

HV: high voltage

MW: mega watt

AC: alternative current

DC: direct current

IT: information technology

EDIW: economic dispatch problem incorporating the wind energy

NLP: Nonlinear programming

RTP: Real-time pricing

PAR: Physical Action Reaction

ANN: Artificial Neural Network

2D: two dimensions

3D: three dimensions

ABC: Ant Bee Colony

BBO: Biogeography-based optimization

LI: Lambda Iteration

HM: Hopefield model

QP: Quadratic Programming

GAMS: General Algebraic Modeling System

DE: Differential Evolution

ELD: economic load of dispatch

PS: pattern search

AGC: automatic generation control

CCHP: Combined Cooling, Heat and Power

FCPPs: fuel cell power plants

EV: electrical vehicle

AMI: advanced metering infrastructure

DG_s: distributed generations

CSA: cuckoo search algorithm

MCSA: modified cuckoo search algorithm

Signs :

ρ = Air Density

A = Area

V= Velocity of Wind

M= the air mass which is passing through the area A in a given time.

a_i= constant specific to each plant

b_i= constant specific to each plant

c_i= constant specific to each plant

P_{gi}=active power generated per unit of generation (i).

$F(P_{gi})$= the cost function of the plant (i).

Ng= number of generators

$F_C$is the total fuel cost of generators,

Nx is the number of generator units,

P_i is the output power of generation unit i,

a_i, b_i and $c_i$are the fuel cost coefficients.

e_i, f_i are the fuel cost coefficients

P_i^{min} is the minimum active power output of the i th generating unit.

W_CIs the total cost of wind power.

Nw Is the number of wind turbines

C_{di} Is direct cost for wind turbine i.

C_{pi} is underestimate cost for wind turbine i

C_{ri} is overestimate cost for wind turbine i.

$w_i^{sc}$is the scheduled wind power for the i th wind turbine.

w_i available wind power for the ith wind turbine.

d_i, $kp_i$and kr_i are the available, penalty, and reserve cost coefficients for the i th wind turbine

$B_{ij}$is the jth element of the loss coefficient square matrix,

B_{0i} is the ith element of the loss coefficient vector,

B_{00} is the loss coefficient constant

P_i^{min},the minimum active power output of the ith generating unit

P_i^{max} maximum active power output of the i th generating unit

$DR_i$is the down ramp limit of the i th generator

$UR_i$is the up-ramp limit of the i th generator.

$P_{i,k}^{l}$ the lower bound of the ith prohibited zone of the ith generating unit

P_{i,n_i}^{u} upper bound of the ith prohibited zone of the ith generating unit

n_i is the number of prohibited zones of the ith generating unit.

w_i^r, is the rated active power output of the i th wind turbine unit

t is the current iterations

$\overrightarrow{X_P}$is the position of the prey

$\vec{X}$ is the position of the grey wolf

$\overrightarrow{A}.\vec{C}$are thecoefficient vectors

α /β /γ/$\delta$are the agents of grey wolves

r_1,$r_2$are allow wolf to reach any position between 2 particular points

General introduction

General introduction

In the early days of electricity, electric systems were small and highly localized. Today's power grid has evolved to become a large interconnected networks that connects thousands of generating stations, transmission lines, distribution networks and load centers. The actual birth of the Smart Grid is unspecified. It is a case of an evolution that started almost as soon as grids started electrical distribution. With the transmission and distribution of power comes a need to monitor consumption, prices and services. Reliability and energy efficiency are fundamental requisites of the electric power grid. In addition, nations around the world are transitioning to renewable energy to reduce greenhouse emissions, mitigate climate change and ensure sustainable energy in the future. The modernization of the electric power grid is central to these efforts. Smart Grid projects are usually associated with smart meters. Smart meters that provided information back to the electric utility came into the picture in the 1970s and were widely used in the 1980s. For Pacific Gas and Electric Company, it was then a small one-watt radio that permits a two-way communication between customers and, thereby enabling customers to review their consumption [1]

The use of renewable energy increased greatly just after the first big oil crisis in the late seventies. Although in most power generating systems, the main source of energy (the fuel) can manipulate, this is not true for solar, water and wind energies. There are many renewable energy sources available in the world. The basic part of these kind of energy sources are free and available. Here will be described all the renewable energy technologies and worldwide their production capacity The main problems with these renewable energy sources are cost and availability; wind, hydro and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not “dispatch able” the power output cannot control. Daily and seasonal effects and limited predictability result in intermittent generation. Smart grids promise to facilitate the integration of renewable energy and will provide other benefits as well, most smart grids are located aside from closely populated areas, near a fuel source and at a dam site, to take advantage from the renewable energy sources. They are usually quite large to take benefits of the economies of scale. Wind power is an alternative source to fossil fuels. Where, wind power is plentiful, renewable, no emission and used the little land for installation as well. This is a better effect on the environment than other power sources.

The economic dispatch problem (EDP) is one of the fundamental issues for energy management during the practical operations of smart grids. The goal of EDP is to allocate the generation power among the generators to meet the load demands with minimal total operation cost (i.e., sum of the local generation costs) while preserving all constraints of local generation capacity. In a sense, EDP can be casted as a constrained optimization problem, which has attracted the attention of a number of researchers in recent years. To solve EDP, many fundamental methods are implemented in a centralized manner. However, these centralized methods demand a powerful centralized controller to collect global information of the entire grid and process a large number of data, which are usually expensive in computation and communication, and prone to single point-failure. With the integration of renewable resources, energy storage devices, plug-in hybrid vehicles and potential consumers, the future of smart grids will be highly distributed, and furthermore will cause the impracticality of traditional centralized method.

To solve the EDP by using meta-heuristic optimization techniques have become very popular over the last two decades especially Genetic Algorithm (GA), Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) which have been applied in various fields of study. There are four reasons meta-heuristic have become remarkably common. There are simplicity, flexibility, derivation-free mechanism, and local optima avoidance. First, they have been inspired by simple concepts with respect to physical phenomena, animals' behaviors, or evolutionary concepts. Second, flexibility refers to the applicability of meta-heuristics to different problems without any special changes in the structure of the algorithm. Third, the majority of meta-heuristics have derivation-free mechanisms. In contrast to gradient-based optimization approaches, met heuristics optimize problems stochastically. Finally, met heuristics have superior abilities to avoid local optima compared to conventional optimization techniques. This is due to the stochastic nature of meta-heuristics which allow them to avoid stagnation in local solutions and search the entire search space extensively. Thus, the new meta-heuristic, GWO proposed by S. Mirjalili is implemented in solving EDP [2]

In this work, we presented Solving the Problem of the Economic Dispatch of Powers in a Smart Electric Grid using the grey wolf optimization GWO method in two cases of study the first one in 6 units system the second one in 15 units system with different wind power penetration rates.

chapter 1 dealt with the smart grid SG and its architecture consisting on the importance of penetration of renewable energies RES on its economic dispatch and their constrains.

chapter 2 contains the optimization techniques and the way of choosing the right method ending by GWO method in solving economic dispatch problem.

The last chapter shows the simulation results in two different power systems divided into method's convergence study (with and without wind power) and wind power penetration rates study and their impact on minimizing the fuel cost.

Chapter I

Economic Dispatch

1. Introduction

The world has recently turned to search for ways to increase the rate of penetration of renewable energies into the smart grid, through special producers and through the application of economic distribution to reduce pricing problems and to control these sources.

This chapter aims to introduce the smart grid (which is characterized by two-way digital communication) and its infrastructure, and the forms of renewable energies with the way of their integration in order to increase the rate of penetration for achieving an orderly economic distribution between production units and ensure a balance between production and consumption.

Accordingly, we presented the distributed generation, and RES forms and their benefits in power grid, taking into account all the constrains that they may face on the economic and technical levels, which ensures the improvement of the network's functioning.

2. General

A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via two-way digital communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. The smart grid was introduced with the aim of overcoming the weaknesses of conventional electrical grids by using smart net meters.

Smart grid technology is an extended form of analog technology that has also been introduced for controlling the use of appliances by employing two-way communication. However, the prevalence of Internet access in most homes has made the smart grid more practically reliable to implement. Smart grid devices transmit information in such a way that enables ordinary users, operators and automated devices to quickly respond to changes in smart grid condition systems.

Smart grid is equally advantageous for enterprises, retail stores, hospitals, universities and multinational corporations. The entire smart grid system is automated for tracking the electricity consumption at all the locations. Grid architecture is also combined with energy management software for estimating the energy consumption and its associated cost for a specific enterprise. Generally, electricity prices increase along with demand. By providing consumers with information about current consumption and energy prices, smart grid energy management services help to minimize the consumption during high-cost, peak-demand times.

A modern smart grid system has the following capabilities:

- It can repair itself.
- It encourages consumer participation in grid operations.
- It ensures a consistent and premium-quality power supply that resists power leakages.
- It allows the electricity markets to grow and make business.
- It can be operated more efficiently.

A smart grid's key features include:

- Load Handling: The sum/total of the power grid load is not stable and it varies over time. In case of heavy load, a smart grid system can advise consumers to temporarily minimize energy consumption.
- Demand Response Support: Provides users with an automated way to reduce their electricity bills by guiding them to use low-priority electronic devices when rates are lower.
- Decentralization of Power Generation: A distributed or decentralized grid system allows the individual user to generate onsite power by employing any appropriate method at his or her discretion [1]

3. Distributed generation

3.1 Definition of distributed generation

Distributed or dispersed generation is defined as opposed to conventional generation, by high-power units connected to the HV network, the location and power of which have been subject to planning, and which are centrally controlled to participate in the control of the frequency and voltage, and ensure reliable and economical operation of the entire network. These centralized units are called “dispatched”. Compared to conventional units, decentralized units are characterized by powers do not exceeding 50 to 100 MW, they are not planned in such a way centralized, nor currently coordinated.[4]

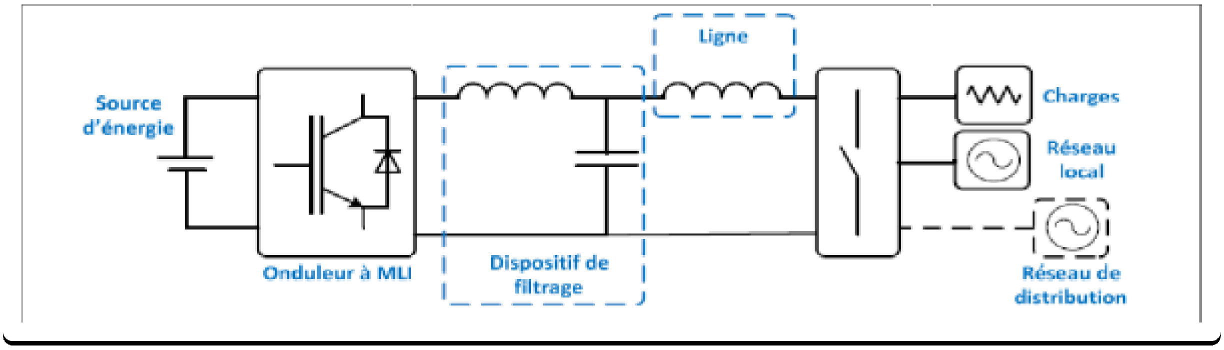


Figure 1.1: Basic structure of a distributed generation unit

3.2 Renewable energy

Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished. For example, sunlight and wind keep shining and blowing, even if their availability depends on time and weather. While renewable energy is often thought of as a new technology, harnessing nature's power has long been used for heating, transportation, lighting, and more. Wind has powered boats to sail the seas and windmills to grind grain. The sun has provided warmth during the day and helped kindle fires to last into the evening. But over the past 500 years or so, humans increasingly turned to cheaper, dirtier energy sources, such as coal and franked gas.[5]

3.3 Forms of renewable energy

3.3.1 Photovoltaic solar

Photovoltaic energy is obtained directly from solar radiation. The signs photovoltaic cells, composed of silicon-based photovoltaic cells, have the ability to transform photon energy into electrical energy. The direct current thus produced is directly usable

3.3.2 Tidal

Tidal power stations can be compared to run-of-river hydraulic power stations. except that the turbines are reversible to take advantage of the ebb and flow of the tides.

3.3.3 Biomass and waste

Agricultural waste, renewable urban waste, biogas and waste from forestry can be used in thermal power plants to generate heat and then power electric. The major interest is that the carbon dioxide released into the atmosphere is compensated by that absorbed by the regrowth of the biomass. The carbon footprint is therefore close to zero.

3.3.4 Solar Thermal

Solar thermal power plants are thermal power plants using steam turbines, the latter being produced by heating water via a heat transfer fluid using solar radiation concentrated on an exchanger by parabolic mirrors.

3.3.5 Geothermal

Geothermal power plants use heat from underground water tables that can reach 350°C in the most favorable areas. This hot water is pumped to the surface to pass through interchanges. The steam produced is turbined in a conventional thermal installation.

3.3.6 Hydraulic

Hydropower plants operate using the gravitational potential energy of water. rivers, lakes or rivers. This is transformed into electrical energy by an alternator driven by a turbine driven by the force of the water which is due either to the height of fall in the case of power stations fed by a penstock, or by flow in the case of run-of-river power stations. Energy hydropower is by far the most widespread renewable energy since it is also used in centralized production.

3.3.7 Wind

Wind turbines, or wind turbines, draw their energy from the wind, which is transmitted, by the rotor and the speed multiplier to a generator. This source of energy, which begins to reach its technological maturity, is more and more answered thanks to its strong ecological appeal.[6]

4. Penetration of renewable energy in power system

Increasing renewable electricity generation is an essential component in achieving a doubling of the renewable energy share in the global energy mix. Such a transition is technically feasible, but will require upgrades of old grid systems and new innovative solutions to accommodate the different nature of renewable energy generation. In particular, smart grids are able to incorporate the following characteristics.[7]

4.1Variability

Some forms of renewable electricity, notably wind and solar, are dependent on an ever-fluctuating resource (the wind and the sun, respectively). As electricity supply must meet electricity demand at all times, efforts are required to ensure that electricity sources or electricity demand is available that is able to absorb this variability.

4.2 Distributed generation

Distributed renewable generation smaller-scale systems, usually privately owned and operated represent a new and different business model for electricity. Traditional utilities are often uneasy about allowing such systems to connect to the grid due to concerns over safety, effects on grid stability and operation, and the dacoities in valuing and pricing their generation.

4.3 High initial cost

Renewable electricity generating technologies typically have higher first costs and lower operating costs than fossil-fueled electricity generating technologies. Although renewable may be “cost-effective” on a lifecycle basis, some electricity systems particularly in developing countries simply do not have access to scent capital to invest in renewable.

Smart grid technologies can directly address these three challenges of renewable electricity generation. In addition, smart grids offer added benefits that can further ease the transition to renewable

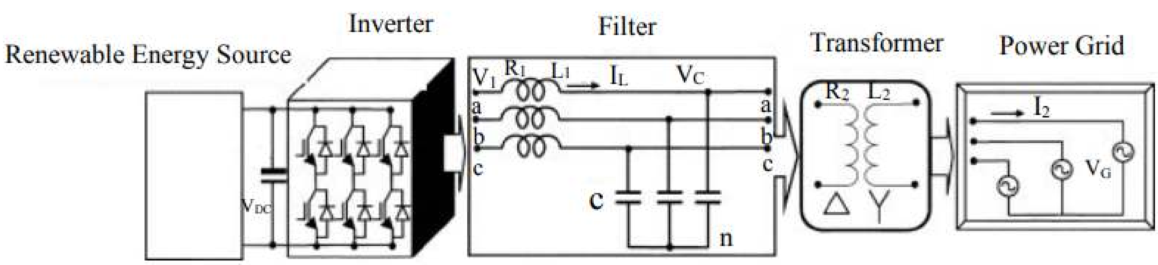


Figure 1.2: General Concept of Renewable Energy-Grid integration

5. Example of Wind power-SG Integration

5.1 History of the Wind Energy

The first simple wind energy devices which was vertical axis wind mills was found thousands of years ago at the Persian Afghan borders around 200BC and the horizontal axis wind mills was found at the Netherlands and the Mediterranean at much later (1300-1875 AD). During the 19Th century further evolutions were made by the Scientists and Engineers in USA [7]. Moreover, different types of wind energy-based instruments (i.e., Musical, working etc.) were used back in time

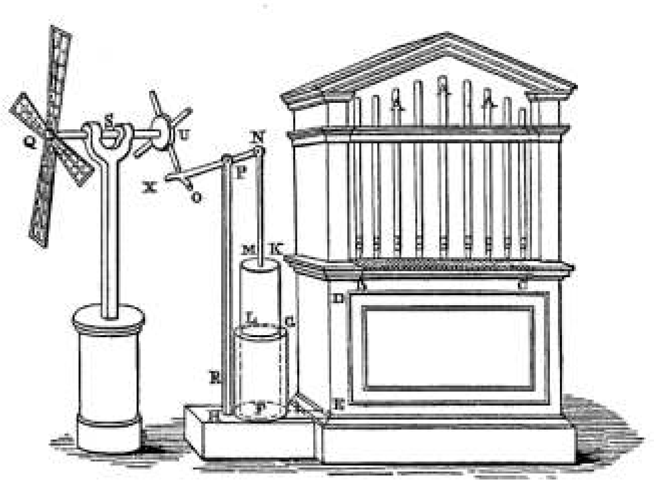


Figure1.3: Ancient wind energy based musical instrument used in first century (AD)

5.2 Components of Wind Power System

The wind power system consists of some mechanical units and operates electrically in parallel.

In general wind power system consists of:

1. The Tower

2. The wind turbines with three or three blades.

3. The yaw mechanism such as the tail vane.

4. The mechanical gear.

5. The electrical generator.

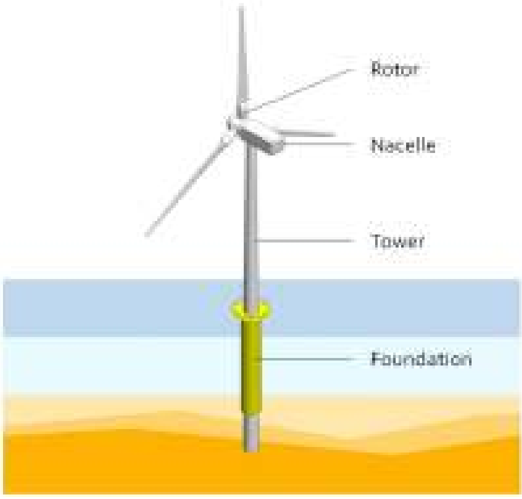
6. The speed sensors and control.

The Modern Wind Power System has the following components:

1. The Power Electronics

2. The Control Scheme, usually involving a computer.

3. The battery for improving the load availability in The transmission line connecting to the area grid stand-alone mode.



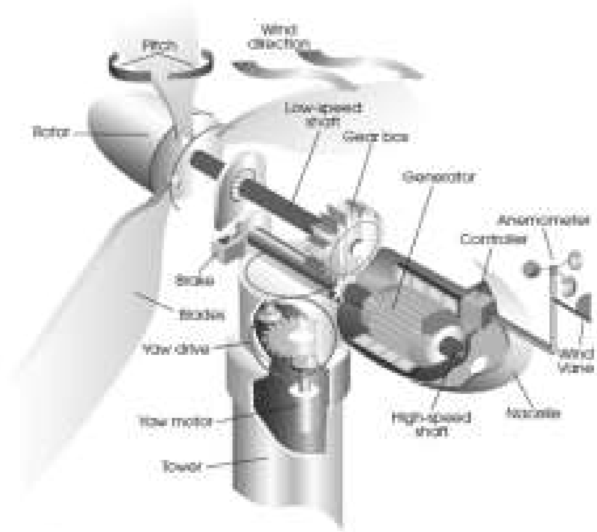


Figure1.4: overview of main components for a wind turbine

5.3 Wind Power Generation

The Power of Wind can be defined as:

$$p_{wind} = \frac{1}{2}\rho A V^3 (1)$$

Where

ρ = Air Density

A = Area

V= Velocity of Wind

The third power of the wind velocity can be expressed in terms of the stated equation below;

$$p_{wind} = \frac{1}{2}\rho A V^3 \qquad (2)$$

M is the air mass which is passing through the area A in a given time.

So, the power of Wind Energy can be described as:

$$p_{wind} = \frac{1}{2}\rho A V^3 = \frac{1}{2} m V^2 = E \qquad (3)$$

5.4 Wind power integration

Integration of wind energy to the grid in terms of increasing efficiency can enhance the power output of the Smart Grid Technology. There is a block diagram of integrating wind to the grid has been given in the figure. We can divide the whole system into three major parts. Beside the wind turbine, there are:

- Turbine & Speed Control Box
- Wind Interfacing Box and
- Grid Connectivity & Transmission to the AC Grid

Turbine and Speed Control Box consists of Power and Speed Control devices such as gear boxes etc. generator, turbine control unit and network switches.

Wind Interfacing Box consists of AC to DC rectifier as the electricity generated from the wind turbine is AC. This rectified DC electricity is transmitted through the DC transmission line and then feed into Battery Bank as the reserve system for further use of electricity. Then the DC transmission line is directed to the DC to AC inverter for the transformation of AC electricity. There is communication control that is done for the purpose of controlling the battery charging and preventing the overcharging problem of battery which affects the battery life span and also the charging limit from the very first time of getting overcharged. These types of communication are done by the optical fibers.

The Grid Connectivity unit is mainly serving the inverted AC electricity directing to the three-phase power line and filters. This is how the AC electricity generated from wind turbine is connected to the grid.[8]

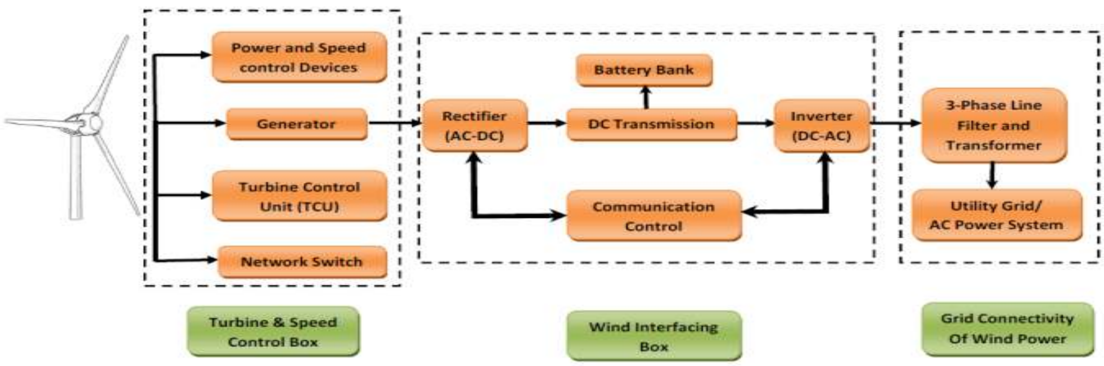


Figure 1.5: Wind Power Generation, control & Grid Connectivity

5.5 Challenges of wind power integration

There are some challenges integrating the wind power to the grid they can be described as below.

5.5.1 Non-Controllable Variability

Non-Controllable variability is the irregularity of the generation of power of wind turbines. Because of variable wind speed there must be fluctuation of the peak voltage of generated electricity. And depending on the weather condition and the air density of the locality where the wind power plant i.e., the wind turbine has been installed, the generated electricity must be varied. So, there must be synchronization unit of the generated electricity.

5.5.2 Location Dependence

Just like the solar power, wind power also has the location dependency. Solar Radiation depends on the position of the location in accordance with the position of the solar. In the same manner wind power depends on the availability of the wind density which varies from region to region. Usually, the locality which is closer to the shore is having the availability of the wind. This is how the wind power integration to the gird depends on the location.

5.6 Benefits of integration of RES in smart grid

The integrated renewable energy resources own good impacts on the grid system, which are defined in three positive aspects.[9]

- **Environmental positive aspect:** The integration of renewable energy resources in grid system enables the fossil fuel power generation plants to decrease the CO_2 emissions in way of less producing the energy.
- **Social positive aspect:** When many persons isolate their own energy source, they receive many advantages such as sale the extra energy to the utility; use their independent source in case of power grid failure.
- **Economic positive aspect:** The integrated renewable energy plays a main role in economic fields by creating new Jobs

6. The economy of smart grids

Smart-grids are so-called "intelligent" networks, which convey information in real time on the conditions of production and consumption between the various players in an electricity system (and gas, secondarily). This technological development creates a break because until then information circulated in a unidirectional mode (from consumers to network managers and producers) and in a generally discontinuous way (manual reading of meters in households remains the most common practice).

Smart-grids thus constitute a convergence between electrical and information technologies, a convergence required both because of developments on the supply side (massive deployment of renewable sources of an intermittent and decentralized nature, such as wind or solar) and demand (development of new uses such as electric vehicles). Thus, the evolution towards these new networks is essential to the current energy transitions towards “low carbon” models. To judge the stakes, note that the main network operators gathered in Seoul in 2011 planned to invest 700 billion dollars in 10 years to support the modernization of their infrastructures.[10]

6.1 New “value chains”

This technological transition opens up new organizations of electrical systems, which economists characterize as new “value chains”. Indeed, traditional players (producers, network managers, suppliers and equipment manufacturers) will see their functions modified by technological developments (advanced metering, storage, etc.), while manufacturers from other fields will also bring their skills (telecommunications, software, IT services, etc.) and that new players, fulfilling new functions, will also emerge (demand response managers, service providers downstream of the meter, electric vehicle charge managers, etc.). In addition, smart grids will involve new forms of economic coordination between “links” of value chains that are more interdependent than before. For example, the development of renewable energies by decentralized producers will cause power fluctuations that will complicate the work of network managers and test their ability to adapt. Above all, the place of the end user will be refocused, since the balance of the electrical system will be focused on controlling consumption, and no longer only on that of production, according to the predominant pattern until now. This refocusing will involve greater price variability, consisting of influencing prices according to production conditions (in order to reduce the use of thermal power stations to cover the peak and to avoid the use of a resource emitting CO2). In pilot projects, consumer behavior is reactive to monetary gains, but also to the interest of contributing to a collective effort. Real-time access to information on electricity consumption produces a consumption reduction effect generally between 5 and 15%, but whose persistence over time is uncertain (so-called “rebound” effect).

6.2 Technical challenges

Most smart-grid projects are at the demonstrator stage so that the “economic models” conducive to their development are still undetermined. Smart-grids nevertheless offer a glimpse of many benefits, starting with the ability of networks to be "self-healing" and "resilient", with a reduction in outages and line losses, as well as an improvement in the quality of service (characteristic important for industrial demand). Combined with progress in home automation, smart-grid infrastructures will allow remote control of household equipment and adaptation of consumption according to offers that promote demand response (smart-home). Beyond housing, smart-grids are tools conducive to the emergence of local energy systems (eco-districts, smart-cities). In competitive terms, the information carried by smart grids will enable better sharing of information on the functioning of energy markets. All these elements combined will directly reduce CO2 emissions (through efficiency gains) – the International Energy Agency estimates that the deployment of smart-grids could reduce peak electricity demand by a quarter on the horizon 2050 or indirectly (through the integration of renewable energies and electric vehicles).

However, the economic valuation of these potential benefits is very uncertain. A smart grid assembles technologies (electrical engineering, telecommunications, software, etc.) that are at different levels of maturity and sometimes not standardized. In addition, the variables essential to the development of "business plans" are very fluctuating (price of fossil fuels and, even more, price of CO2). Ditto for consumers' adoption of demand response services or their willingness to pay for energy-efficient, remote-controlled capital goods. Basically, the evolution towards smart-grids involves the gradual modification of the place of consumers in electrical systems, in which they will have to become fully-fledged players: as the offer can no longer, in all circumstances, adapt to demand, demand will have to make its own contribution to the balance of the system. Much will depend on the ability to renovate the regulators' toolbox and to allocate costs and risks between the actors of the new electricity ecosystems.

For all of these reasons, the gradual introduction of smart grids will constitute a good “marker” of the energy transition, in the sense that these transformations in the networks will only result at the cost of multiple innovations, in technologies naturally, but also in economic models and related regulatory models

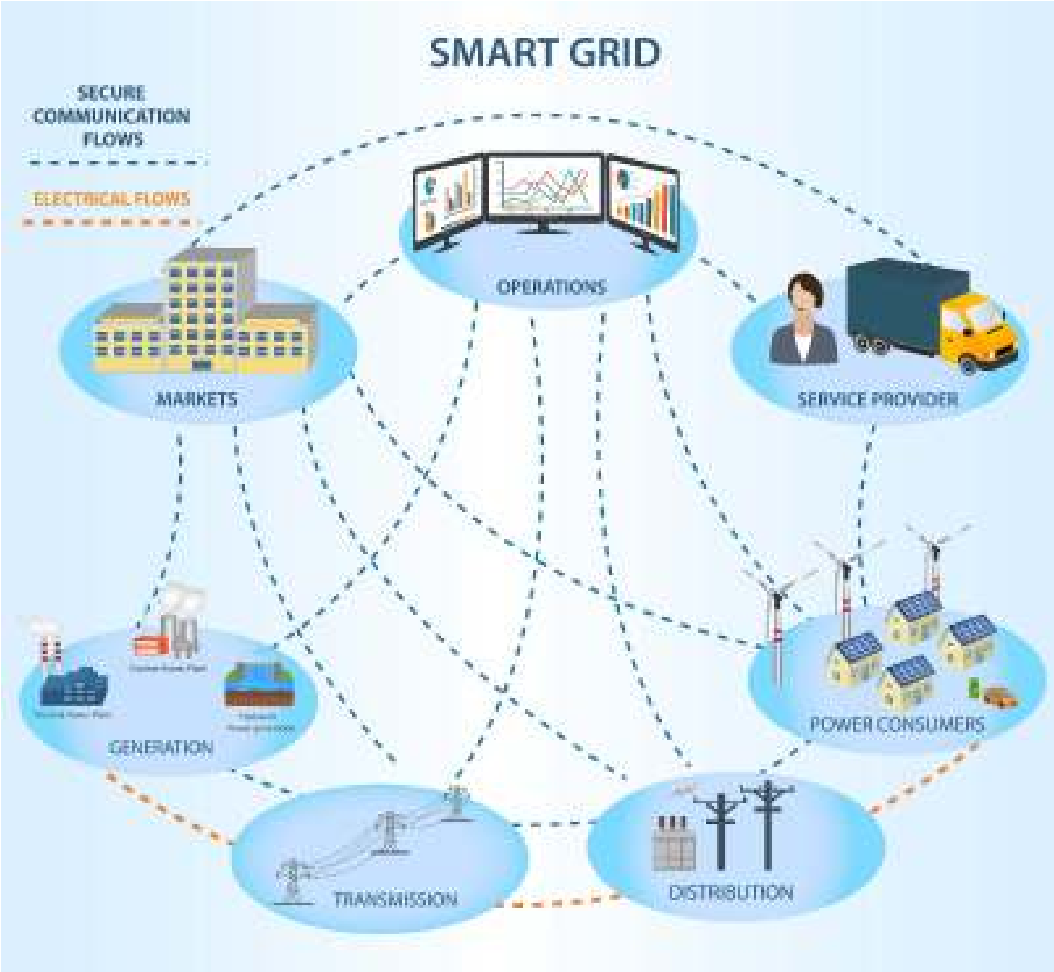


Figure 1.6: smart grid infrastructure

7. Economic dispatch

7.1 Definition

Economic dispatching is a static optimization problem which consists in distributing the production of the active power requested between the various power stations of the network, so as to operate it in the most economical way possible. This distribution must obviously respect the production limits of the power stations. The variable to be optimized is the cost of production.[11]

Different fuel generators have different costs to provide the same amount of electrical energy. It is important to realize that the generator most efficient system cannot produce electricity at the lowest cost and that a cheap generator may not be the most profitable. Since a generator which is too far from the center of the load gives huge transmission losses, and therefore makes it uneconomical to operate.[12]

The objective of the economic dispatching problem is to calculate, for a single period of time, the active power produced for each production unit so that the demand is satisfied at a minimum cost while satisfying the various constraints generator network techniques. The system consists of n generating units.[13]

The functions to be optimized are the cost functions; they are modeled by functions objectives necessary for the optimization operation.

7.2 Mathematical formulations

7.2.1 The objective function

The production cost of a power plant is generally modeled by a function polynomial of the second degree in PG (active power generated by the plant) whose coefficients are constants specific to each unit.[14]

The function coat is a second-order polynomial in terms of P_{gi} in the following form:

$$F_T = \sum_{i=1}^{Ng} (a_i P_{gi}^2 + b_i P_{gi} + c_i) \qquad (4)$$

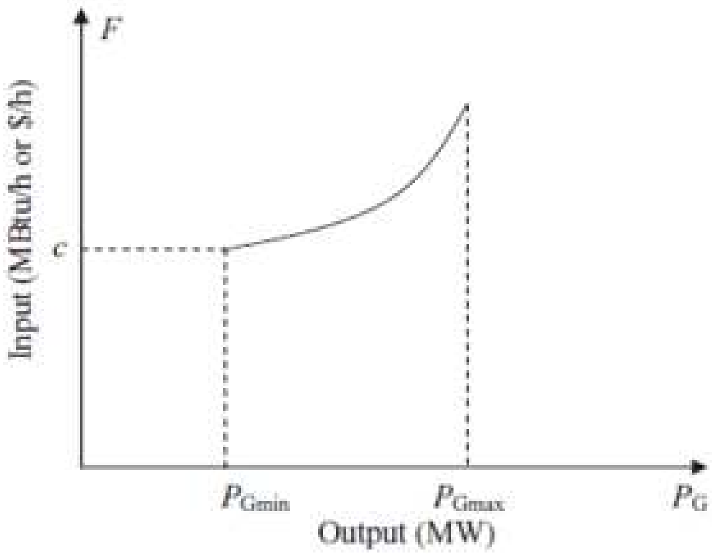


Figure 1.7: input-output characteristic of a production unit.

It is very important to note that other specific characteristics must be taken into account. Consideration for the cost of electricity generation. This is particularly the case for the cost specific to start or stop the production unit (start-up and stop cost), at for example: the start-up cost corresponds to the cost of the energy required to put into operation all the auxiliaries allowing the production of electricity (boilers, pumps, etc.).

This cost normally depends on the state of the production unit at the time of the call for start (cold or warm start) and start time (peak or dip). The technical constraints are also important for operation.

Generally, the unit of production can only operate stably from a production level minimum (minimum production capacity) and up to a maximum level of production (maximum production capacity).

7.2.2 The objective function with wind

The general formulation of the EDIW optimization problem can be stated as follows:

$$\min F_C + W_C \qquad (5)$$

Where

$$F_C = \sum_{i=1}^{Nx} a_i P_i^2 + b_i P_i + c_i \qquad (6)$$

The fuel cost equation considering the valve point effect is given by:

$$F_C = \sum_{i=1}^{Nx} a_i P_i^2 + b_i P_i + c_i + \left| e_i \sin(f_i (P_i^{min} - P_i) \right| \qquad (7)$$

The total wind cost is composed of the sum of three components: direct cost, underestimate cost and overestimate cost as shown in (8).

$$W_C = \sum_{i=1}^{Nw} C_{di} + C_{pi} + C_{ri} \qquad (8)$$

A detail total wind power cost is shown in (9), which show that there are two components that depend on the expected value of exceeding or not exceeding the scheduled value. In both cases there will be cost to be paid, hence there will be an effect on the total cost.

$$W_C = \sum_{i=1}^{Nw} d_i w_i^{sc} + kp_i E_i^{ue} + kr_i E_i^{oe} \qquad (9)$$

Where

E_i^{ue} is the expected value of wi > w_i^{sc} for the i th wind turbine and E_i^{oe} is the expected value of wi < w_i^{sc} for the i th wind turbine.

$$E_i^{ue} = \int_{w_i^{sc}}^{w_r} (w - w_i^{sc}) f_w(w) dw \qquad (10)$$

$E_i^{oe} = \int_0^{w_i^{sc}} (w_i^{sc} - w)\, f_w(w) dw$ (11)

$f_w(w)$ is The transferred Weibull distribution from wind speeds to wind power. The cost model used is will explained in (18).

7.3 Constraints

7.3.1 Equality constraints

- Real Power Balance Constraint:

Equation (12) represent the equality constraint in the problem, where the $P_D$represent the total load demand andP_L is the power losses.

$\sum_{i=1}^{Nw} w_i + \sum_{i=1}^{Nx} P_i = P_D + P_L$ (12)

$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} P_i B_{ij} P_j + B_{0i} P_i + B_{00}$ (13)

B-Coefficients:

These are also called the loss coefficients, assumed to be constant for a base load range, and reasonable accuracy is expected when operating conditions actual operating conditions are close to the base case conditions used to calculate the coefficients. They are usually represented by B_{ij}.

7.3.2 Inequality constraints

- Generator Power Limit Constraint:

Generation units are restricted by their limits in term of generation active power as follows:

$P_i^{min} \leq P_i \leq P_i^{max} i = 1,2, \ldots N_x$ (14)

Where P_i^{min},P_i^{max} , are the minimum active power output, maximum active power output of the i th generating unit respectively.

- Ramp Rate Limit Constraint:

Within the range of production levels (e.g., the time it takes to move from one production level to another while respecting the turbine's safe thermal gradients)

If power generation increases

$P_{inew} - P_{inow} \leq UR_i$ (15)

If power generation decreases

$P_{inow} - P_{inew} \leq DR_i$ (16)

Where P_{inow} (in MW) is the previous output power and UR_i (in MW/h) is the up-ramp limit of the ith generator; and DR_i (in MW/h) is the down-ramp limit of the ith generator.

- Prohibited Operating Zone Constraint: (normally will be given by the manufacturer)

In the actual power system, the load demand of a power system must avoid the prohibited zones. Thus, if the constraint in (4) is taken into account, the feasible operating zones of the ith generating unit can be as follows

$$P_i^{min} \leq P_i \leq P_{i,1}^{l}$$

$$P_{i,k-1}^{u} \leq P_i \leq P_{i,k}^{l}$$

$$k = 1,2,3,,,,n_i$$

$$P_{i,n_i}^{u} \leq P_i \leq P_i^{max}$$

(17)

where $P_{i,k}^{l}$and $P_{i,n_i}^{u}$are the lower and upper bound of the jth prohibited zone of the ith generating unit, and n_i is the number of prohibited zones of the ith generating unit. In the actual power system, the load demand of a power system must avoid the prohibited zones.

- Wind turbine Power Limit Constraint:

$0 \leq w_i \leq w_i^r i = 1,2 \ldots N_w$ (18)

Where w_i^r, is the rated active power output of the i th wind turbine unit

8. Conclusion

Through this chapter, we conclude that the smart grid is facing a lot of economic problems, the most important one is concerning minimizing the cost of production by minimizing the power produced of each unit .in this case we study the impact of wind power in SG economic dispatch which is subject to some contains that must be taken into account, which can be improved by using optimization methods.

Chapter II

Optimization Method

1. Introduction

The design and operation of systems or processes to make them as good as possible in some defined sense. The approaches to optimizing systems are varied and depend on the type of system involved, but the goal of all optimization procedures is to obtain the best results possible (again, in some defined sense) subject to restrictions or constraints that are imposed. While a system may be optimized by treating the system itself, by adjusting various parameters of the process in an effort to obtain better results, it generally is more economical to develop a model of the process and to analyze performance changes that result from adjustments in the model. In many applications, the process to be optimized can be formulated as a mathematical model; with the advent of high-speed computers, very large and complex systems can be modeled, and optimization can yield substantially improved benefits.

Optimization is applied in virtually all areas of human endeavor, including engineering system design, optical system design, economics, power systems, water and land use, transportation systems, scheduling systems, resource allocation, personnel planning, portfolio selection, mining operations, blending of raw materials, structural design, and control systems. Optimizers or decision makers use optimization in the design of systems and processes, in the production of products, and in the operation of systems.

The first step in modern optimization is to obtain a mathematical description of the process or the system to be optimized. A mathematical model of the process or system is then formed on the basis of this description. Depending on the application, the model complexity can range from very simple to extremely complex.[15]

2. GENERAL

2.1 Definition

An act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible specifically the mathematical procedures (such as finding the maximum of a function) involved in this.[16]

2.2 What do we need to optimize?

2.2.1 Objective function

- This is the most important thing in optimization; we need to know what we want to improve to the extreme. [19]

- Extreme can be a maximum or minimum, depending on the identified objective.
    - It is a cost, we minimize; and if it is profit, we maximize.
    - In structures, if it weight, we minimize; and if it is strength we maximize, most often.
- We call it an objective function because it must depend on some variables in order to optimize.
    - The objective function should be a function of optimization variables.

2.2.2 Optimization variables

These are the variables to which we try to assign suitable values to optimize the objective function.

2.2.3 Constraints

- Quantities that should be within bounds while we optimize the objective function.
- Constraints too are functions of optimization variables.

2.2.4 Formulae or methods to quantify and compute objective function and constraints

- We should have either mathematical expressions (formulae) or numerical methods to compute the values of the objective function and constraints once we know the values of the optimization variables.

There will be subsidiary variables too

There will also be constraints that govern those subsidiary variables. Subsidiary variables are called state variables in the context of structural optimization.[17]

2.3 How to choose the right optimization method?

To choose the most appropriate method for a particular problem, the main characteristics taken into account are.

2.3.1 The ability to avoid local minima

For example, if the objective function is convex, it may be recommended to use a local method that is quickly optimized compared to the global optimization method. That said, if the objective function is multimodal, it may not be worthwhile to apply the local method, which is necessary to adopt a global approach. Although there are several methods here.

2.3.2 Best robustness

The robustness of optimization is also a key concept of the designer, which should not be neglected when choosing an optimization algorithm.

2.3.3 Ability to handle single or multi-objective problems

Multi-Objective optimization is a very active research area because of the enormous economic and industrial risks. Multi-Objective optimization methods allow designers to provide a set of solutions that correspond to the different problems of many compromises between objectives.

2.3.4 The speed of convergence

That is, what is the number of variables to evaluate to converge towards a global optimum? The answer to this question lies in the compromise that must be found between exploration and exploitation.[18]

2.4 Classification of optimization techniques

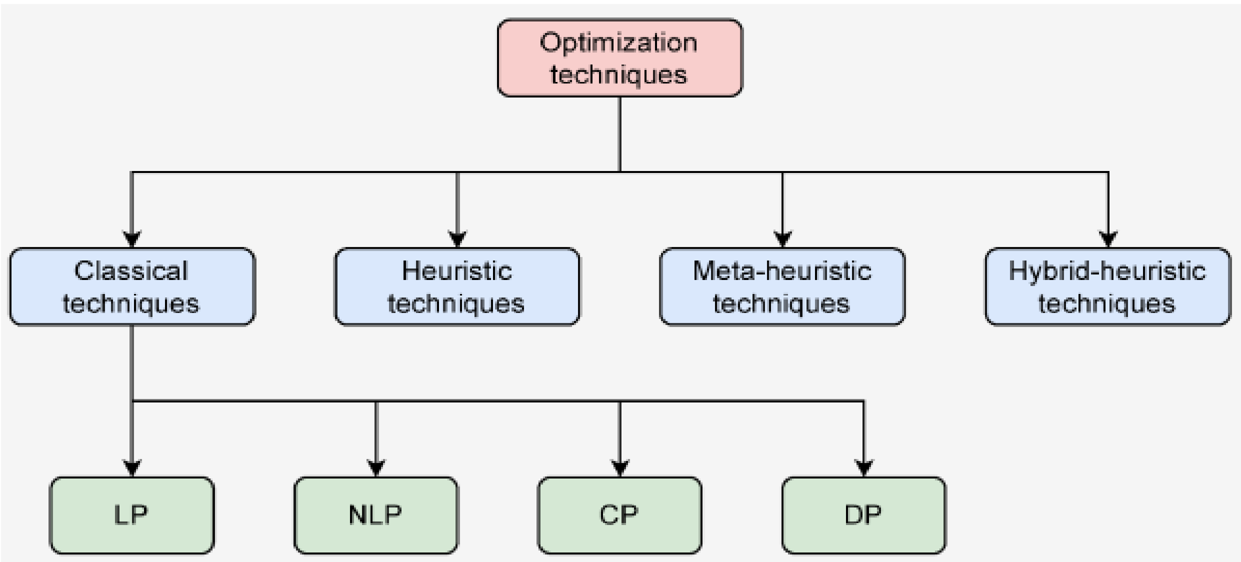


Figure 2.1: classification of optimization techniques

2.4.1 Classical optimization method

2.4.1.1 Linear Programming

Linear programming uses a mathematical model to describe the problem with linear objectives and linear constraints. The general structure of problems solved by this method is:

Maximize $C^T x$

s.t. $Ax \leq b$

and $x_i \geq 0 \quad \forall_i \in \{1, n\}$

2.4.1.2 Nonlinear Programming

Nonlinear programming (NLP) typically employs Lagrangian or Newtonian techniques for constrained and unconstrained optimization problems. The approach assumes that all objective functions are modeled as smooth and continuous functions. However, the mathematical response of the power system diverts from this assumption in many instances. The general structure of problems solved by this method is:

Maximize f(y)

Subject to

$C_i \leq f(y) \leq D_i \forall_i \in \{1, n\}$

2.4.1.3 Convex Programming

Conic programming, least squares, geometric optimization, and Lagrange’s method are used to tackle convex programming problems. With recent advances in optimization algorithms, convex programming is now nearly as simple as linear programming. Convex programming techniques are usually used in demand response programs. In, the authors have used RTP evaluated convex optimization technique to minimize electricity cost and energy consumption.

2.4.1.4 Dynamic Programming

This approach was developed to solve sequential, or multistage, decision problems. Basically, it solves a multivariable problem by solving a series of single variable problems. This is achieved by tandem projection onto the space of each of the variables. In other words, it projects first onto a subset of the variables, then onto a subset of these, and so on. It is a candidate optimization technique for handling time variability and noise in the objective and constrained optimization problem.

2.4.1.5 Heuristic and Meta-Heuristic Optimization Techniques

For solving large problems, conventional techniques using mathematical optimization are computationally expensive. Heuristic and meta-heuristic techniques offer good alternatives. They rely on the high-level procedure to search for solutions resulting in a lower computational burden than conventional techniques. The heuristic techniques are particularly useful for the problems where it is useful to find one sub-optimal solution. Meta-heuristics are very popular optimization algorithms for solving formidable optimization problems. They are more efficient than conventional techniques with mathematical optimization because of the large search space to find an optimal solution.

2.4.1.6 Hybrid Heuristic Techniques

A combination of two or more algorithms is considered a hybrid approach. Compared with single algorithms, the hybrid algorithms perform better for cost reduction, PAR reduction, and consumer comfort satisfaction. A hybrid evolutionary approach with PSO and neuro-fuzzy logic is proposed to eliminate the uncertainties of electricity rates.[19]

Table 2.1: The optimization target with the right optimization method[20]

Optimization target	Optimization method
Min cost	Integer linear program-author’s software Mixed integer linear program-simulated annealing Mixed integer non-linear program-commercial software Convex optimization-relaxed convex programming technique Heuristics-greedy search algorithm Heuristics-evolutionary algorithm
Min aggregated power	Integer linear program-branch and bound method Convex optimization-parallel distribution computation Particle swarm optimization-signalledpso Mixed integer linear program-model predictive control
Min (cost and power)	Mixed integer linear program-commercial software Mixed integer linear program Game theory-author’s software

2.5TYPE OF OPTIMIZATION PROBLEMS

There are many, many types of optimization problems; The types arise because of:

- How many objective functions you have
- Types of objective function and constraints.
- Types of variables.
- Nature of optimization we want to do.

- Global
- Local

2.5.1 Classification based on the objective function

2.5.1.1 One or more objective functions

Working with a single objective is easy

- Most of the theory of optimization is focused on dealing with a single objective function.

Multi-objective optimization is hard.

- Weights can be given but then how do you give the weights when you do not know which objective is more important for you?
- The best thing to do is to move the less important objective to a constraint.

Pareto optimum

- Pareto optimum concept is an important concept in multi-objective optimization.
- Pareto optimum is one where you can improve on objective function without hurting another.
- Often, Pareto optimum will be a set; that is there will be many Pareto optima.
  - Pareto optimum set can be continuous or discontinuous.
  - Generating the entire Pareto set is difficult in practice.

2.5.1.2 Global or local

a) Local optimum is one in a small vicinity of the optimum point.

- It is like you are the smartest in your class. You are a local maximum.

b) Global optimum is one that considers the entire domain of the objective function.

- If your school beauty is a local maximum, Miss Universe if the global optimum.

2.5.2 Classification based on constraints

2.5.2.1 Without constraints

If there are no constraints, it becomes an unconstrained optimization problem.

2.5.2.2 With constraints

With constraints, it is constrained optimization problem.

Equality or inequality

a) Constraints can be equalities.

b) Governing equations are usually equality constraints in structural optimization.

c) They can be inequalities.

d) Inequalities arise mostly due to resource and performance constraints in structural optimization.

Constraints reduce the permissible values of the optimization variables

- Constraints constrain the space of optimization variables.

Feasible space :

a) The space of optimization variables where all constraints are satisfied is called the feasible space.

b) In constrained optimization, we need to search for the optimum of the objective function only in the feasible space.

c) Constructing feasible space is often impractical but we can certainly search within it.

2.5.3 Classification based on objective and constraints

2.5.3.1 Linear programming

- Both objective function and constraints are linear.

2.5.3.2 Nonlinear programming

- Both objective and constraints are nonlinear.

2.5.3.3 Quadratic programming

- Objective function is quadratic and constraints are linear.

2.5.3.4 Geometric programming

a) Objective and constraints are posynomials.

b) Posynomials are polynomials with positive coefficients.

c) Positive + Polynomial = posynomial A portmanteaus word.

d) Exponents in posynomials can be real numbers, positive or negative, in the context of geometric programming.

2.5.3.5 Convex optimization

- The objective function is convex and so is the feasible space.

2.5.3.6 Non-smooth optimization

- Where either objective function or the constraints, or both, are not differentiable.

2.5.4 Classification based on the nature of optimization

2.5.4.1 Global or local

a) Local when we are happy with a local minimum.

b) That is smallest in the vicinity of a point.

c) Global when we want to find the smallest among all minima There are no easy methods to find the global minimum.

- Only special types of problems allow finding the global minimum.

2.5.4.2 Deterministic or stochastic

a) Deterministic means that you have the same thing any number of times you try it.

b) Stochastic means that there is also an element of randomness in addition to deterministic nature.

c) An optimization problem can be stochastic if the variables involved are stochastic.

d) But, one can use non-deterministic methods to solve a deterministic problem.

- Genetic algorithms, Simulated annealing methods, Monte Carlo search, etc.

2.5.5 Classification based on types of variables

2.5.5.1 Continuous or discrete

a) Discrete

- Binary
- Only 0 or 1 are allowed.
- Integer
- Discrete sets
- Bearing sizes, screw threads, etc.; you cannot have whatever you want. They will be certain pre-specified values

b) Continuous

- Decision variable can take any real value.

2.5.5.2 Deterministic or stochastic

- Uncertainties bring about stochastic nature in structural optimization.

2.5.5.3 Finite variables or functions themselves?

a) Variables are finite if they are like x1, x2, x3, … ,xn.

b) What if variables are not finite?

c) What if variables are functions themselves?[17]

3. Grey Wolf Optimizer (GWO)

3.1 Definition and principal

Grey Wolf Optimizer (GWO) is one of the listed met heuristic methods. The GWO is built based on the wolf hunting behaviors from the types of Canes lupus of the Canidae family. In the food chain, the grey wolf is dominating the chart as apex predators. Hence, it shows the domination of the wolf when hunting for their food/prey. The grey wolf hierarchy exists in a pack which is led by the alpha, beta, delta and omega as shown in Fig. 1. The alpha wolf, which can be either male or female grey wolf, dominates the hierarchy by being the leader in a pack. The alpha will decide on certain things especially hunting, place to sleep, waking time and many more. While the beta acts as the sidekick, it will help the alpha in making decision and will replace the alpha if anything happened to the current alpha. The delta and the omega are at the lowest rank in the grey wolf pack. Both are almost of equal type with only slight difference on their dominating character whereby the delta tends to dominate the while giving service to the alpha and the beta. The omega plays as a scapegoat in order to submit themselves to the other dominant wolves. This shows that the omega is of the least important in the pack of the wolves.[21]

The grey wolf hunting has three main phases as shown in Figure 2.3 the phases include tracking, chasing and approaching the prey. The grey wolf hunting also includes pursuing, encircling and harassing the prey until it stopped moving and attacking the prey. Based on this, the behavior of the grey wolves is then being designated by mathematical model and the optimization is performed.

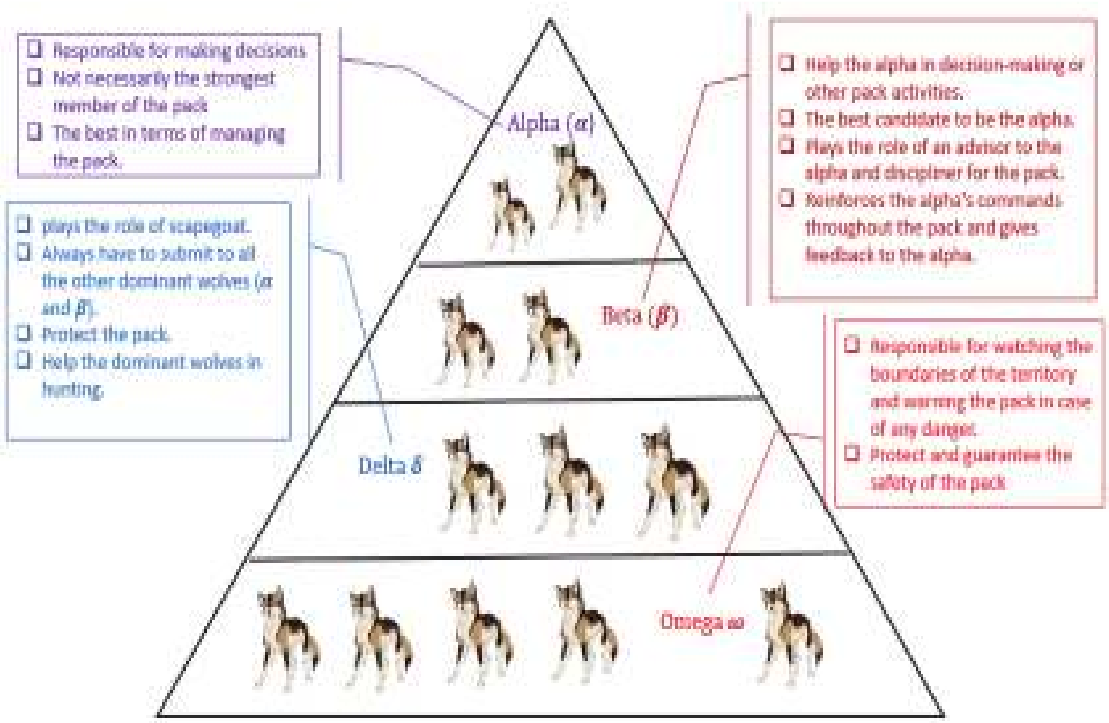


Figure 2.2: The social dominant hierarchy of grey wolves

Figure 2.3: The hunting behavior of the grey wolves

3.2 Steps of GWO

3.2.1 Search for prey (exploration)

According to the position of alpha, beta and delta, they diverge from each other to search and converge to attack the prey. Here A is utilized as greater than 1 or less than −1 to indicate the search agent to diverge and converge from the prey. This also emphasizes exploration and allow for GWO search globally. The whole searching process starts when any possible locations of the prey were estimated and at some point, the position and the distance of the prey will always be updated. The parameter α will be decreased to emphasize the exploration and exploitation towards the prey (optimum). The wolves will move to the prey. The wolves will then diverge and converge towards their prey. Finally, the algorithm will be withdrawn as the wolves reach their satisfaction which is when the prey's location is obtained and acknowledged by all wolves (nearest to the prey). The flowchart of the GWO is summarized in Figure2.4 below [21]

3.2.2 Mathematical model of encircling the prey

Grey wolf encircles the prey during hunting. Encircling behaviors is modeled as:

$$\vec{D} = \left|\vec{C}.\overrightarrow{X_P} - \vec{X}(t)\right| (1)$$

$$\vec{X}(t+1) = \left|\overrightarrow{X_P}(t) - \vec{A}.\vec{D}\right| (2)$$

Where t = current iterations

$\overrightarrow{X_P}$ = position of the prey

$\vec{X}$= position of the grey wolf

$\vec{A}.\vec{C}$ = coefficient vectors

$\vec{A}.\vec{C}$ vectors are calculated as:

$\vec{A}= 2.\vec{a}.\vec{r_1}-\vec{a}$(3)

$\vec{C} = 2.\vec{r_2}$(4)

The above equations are used to update grey wolf position according to the position of the prey

Different places around the best search agents can reached w r t current position by adjusting the values of A and C

r_1,r_2 allow wolf to reach any position between 2 particular points.

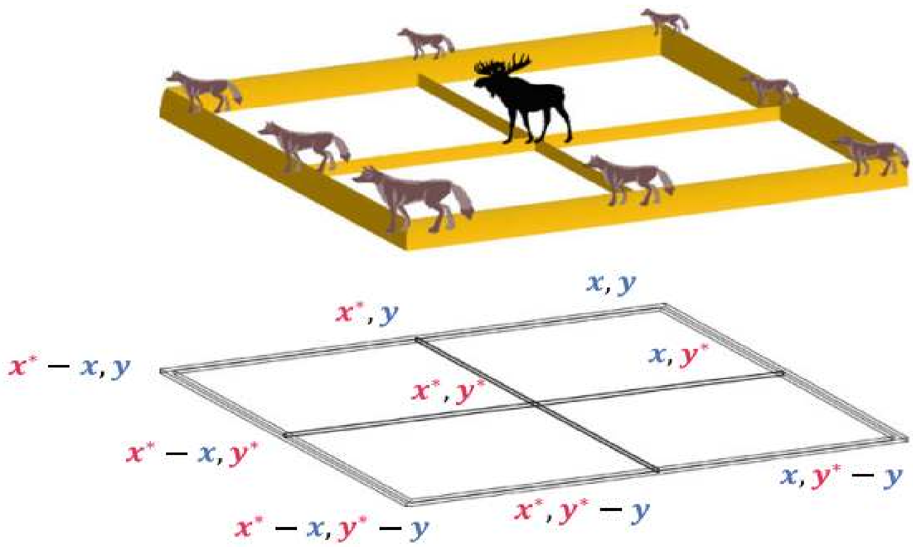


Figure 2.4:The position of a wolf can be defined around a prey with considering a 2D mesh around the prey

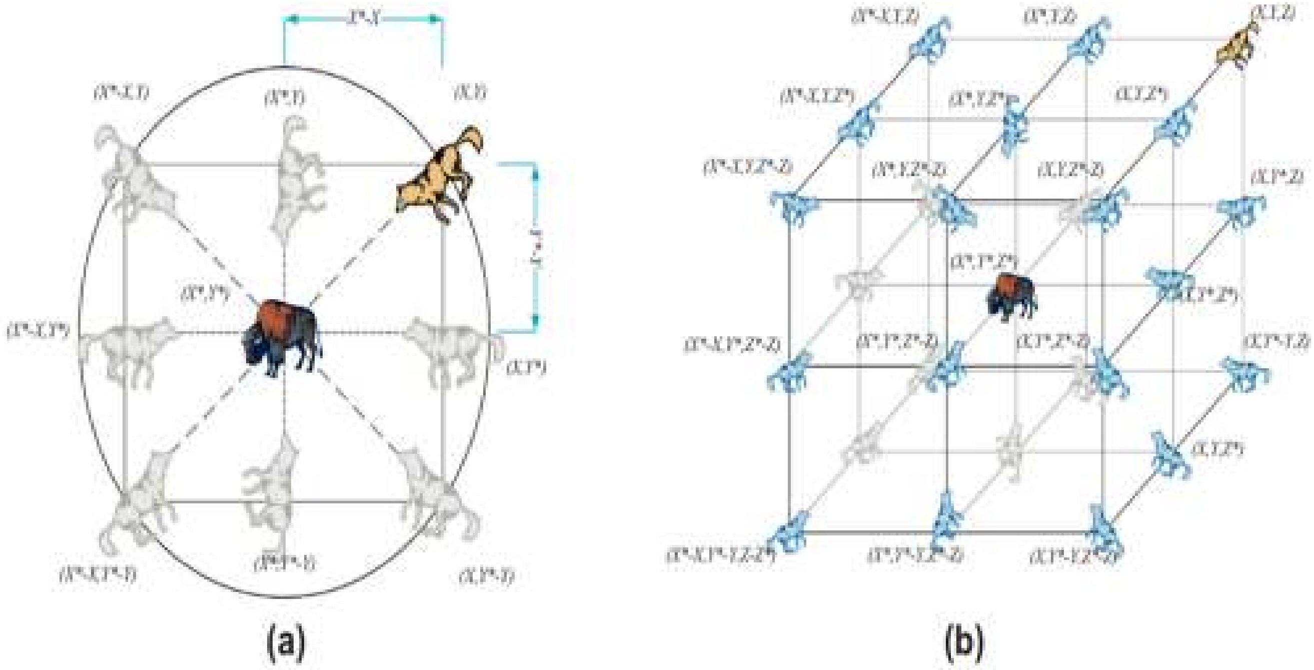


Figure 2.5. 2D and 3D position vectors and their possible next locations

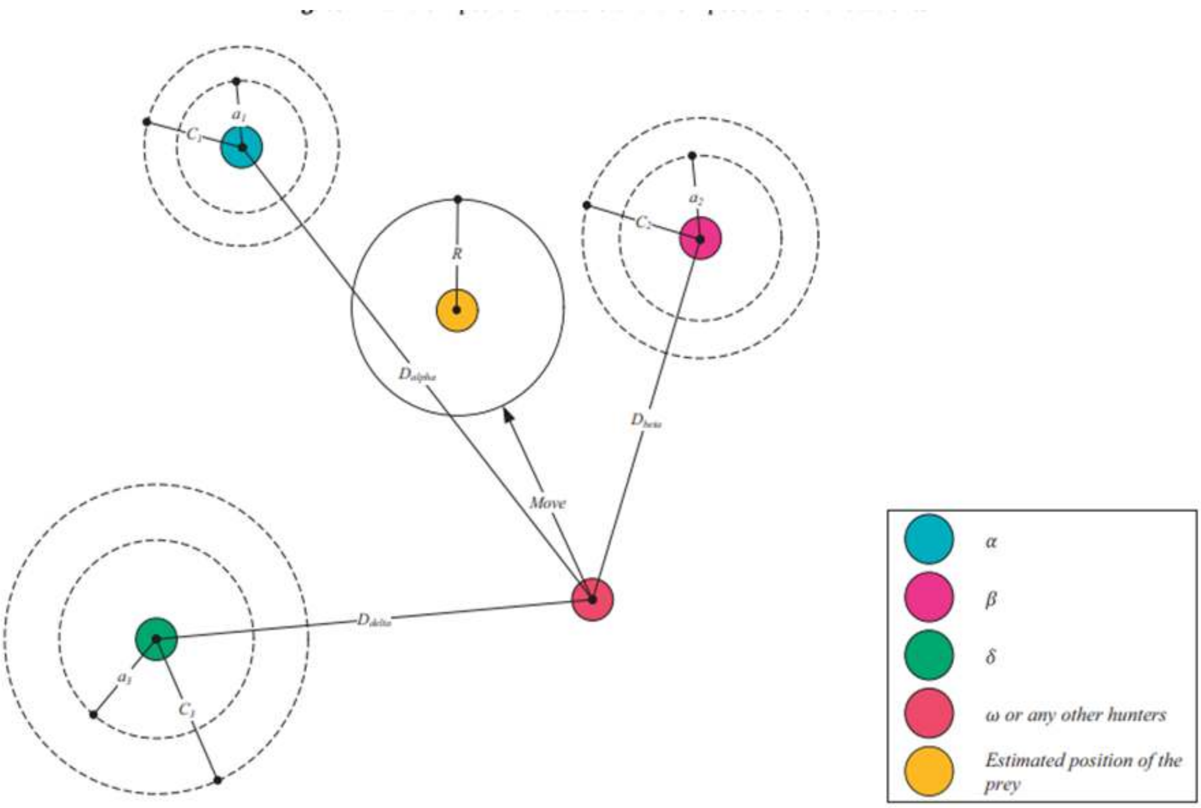


Figure 2.6: Position updating in GWO

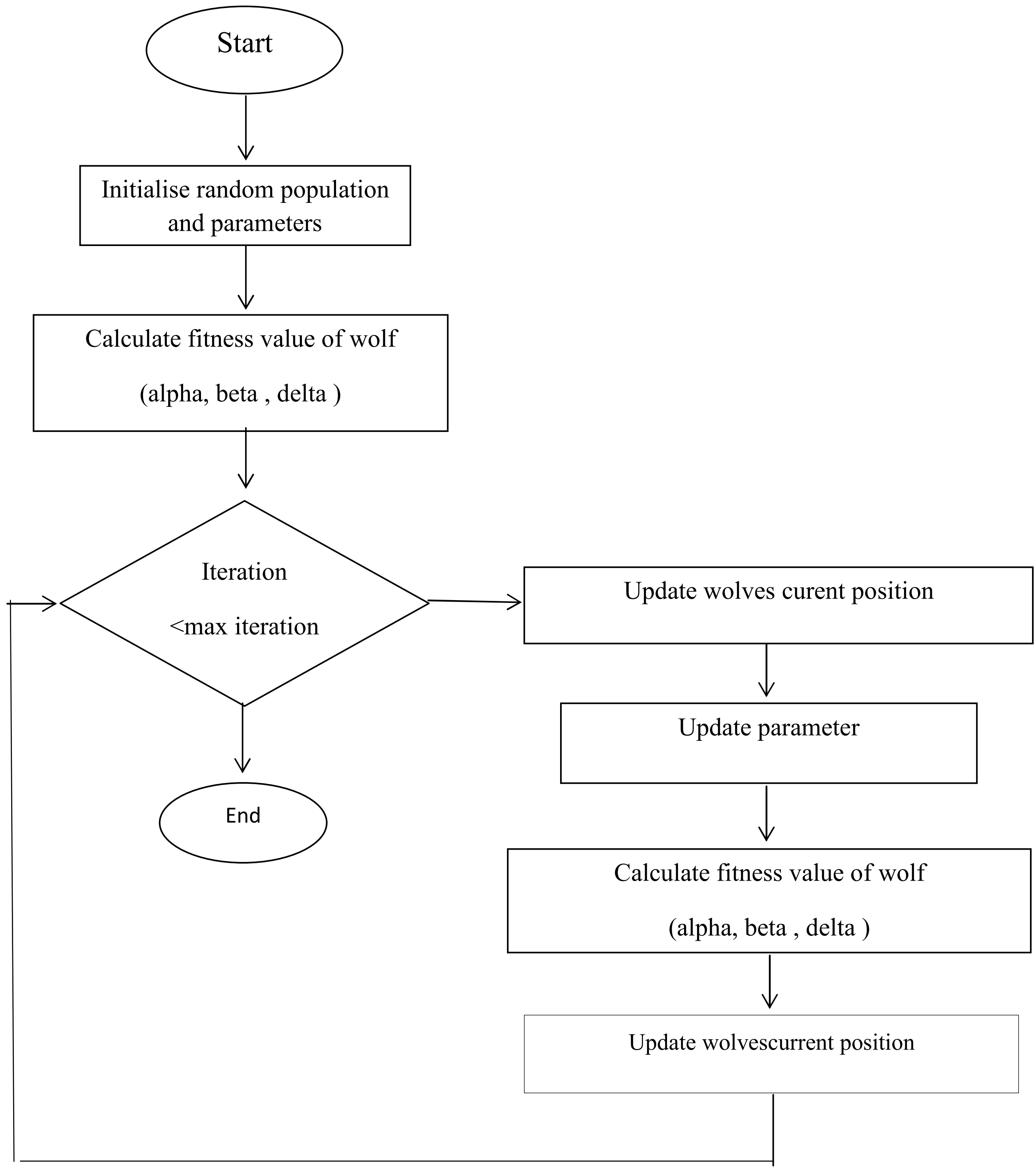


Figure 2.7: The flowchart of the GWO

3.2.3 Hunting

The grey wolves' will naturally recognize the location of their prey and will usually encircle their food. This will be led by the alpha, beta and delta followed by the omega. Some of the prey's locations (optimum) searched by the wolves are not known by humans. Thus, to understand their behavior, representation of a mathematical equation was made to mimic their behavior by assuming alpha (best candidate solution), beta and delta have a bigger knowledge about their prey's location. With that, the first three wolves were saved as the best three candidates' solution by the time being while the other wolves (omega) updated their position according to the best search candidate. The equations are shown in formulations 5, 6 and 7 below:

$$\overrightarrow{D_\alpha}=\left|\overrightarrow{C_X}.\overrightarrow{X_\alpha}-\vec{X}\right| \;.\; \overrightarrow{D_\beta}=\left|\overrightarrow{C_2}.\overrightarrow{X_\beta}-\vec{X}\right| \;.\; \overrightarrow{D_\delta}=\left|\overrightarrow{C_3}.\overrightarrow{X_\delta}-\vec{X}\right| (5)$$

$$\overrightarrow{X_1}=\overrightarrow{X_\alpha}-\overrightarrow{A_1}.\left(\overrightarrow{D_\alpha}\right)\overrightarrow{X_2}=\overrightarrow{X_\beta}-\overrightarrow{A_2}.\left(\overrightarrow{D_\beta}\right) \quad . \quad \overrightarrow{X_3}=\overrightarrow{X_\delta}-\overrightarrow{A_3}.\left(\overrightarrow{D_\delta}\right) \quad (6)$$

$$\vec{X}(t+1)=\frac{\overrightarrow{X_1}+\overrightarrow{X_2}+\overrightarrow{X_3}}{3} (7)$$

The final positions of the wolves will be at random place within a circle by the control of formulations 3 and 4. In addition, the alpha, beta and delta will estimate the position of the prey while the other wolves set their positions randomly around the prey[21].

3.2.4 Attacking prey (exploitation)

The grey wolves will finish their hunt by attacking the prey when it stops moving. The value of α and A is a decade. A is a random value in the interval [− α, α] where it will be a limitation of the movement for the wolves to search for the prey. The searching is controlled by the decrease of the interval in α and A. Where α decreases from 2 to 0 which made it nearer to the prey over the iterations.[21]

3.3 Recent studies on the application of the GWO

The application of the GWO in various fields clearly shows how effective the GWO is, even though there are some repetitions of the usage in some of the fields, but the basic GWO or hybrid or improved technique still gave better performance in solving the optimization problems. From the previous studies, many researchers have used the GWO and applied this method in various fields such as electrical engineering, gene classification, forecasting and etc. The applications of the GWO are separated according to specific fields and are enclosed in the sections below[21]

3.4 GWO and Economic dispatch problems

Applied the GWO in economic dispatch problem to obtain low transmissions loss and minimize the total fuel cost. The GWO method is being compared with the Firefly algorithm, Ant Bee Colony (ABC), Biogeography-based optimization (BBO), Lambda Iteration (LI), Hope field model-based search (HM), Neural Network trained by ABC, Quadratic Programming (QP) and General Algebraic Modeling System (GAMS). The results showed that besides being able to achieve the aim of the study, the GWO appeared to be the most outstanding method of all. Studied the GWO to solve optimum reactive power dispatch for nonlinear optimization problem in electrical power system. The result showed that controllable variables from best combination were performed in order to achieve minimum voltage deviations

The investigated ways to get the minimum cost using economic dispatch problem by combining fuel-based power generation. It was revealed that the GWO was able to give the most competitive and promising result when compared to various types of methods. proposed a hybrid GWO with Differential Evolution (DE) type mutation and crossover in solving economic dispatch problem which is nonlinear, non-convex and discontinuous in nature with various inequality and equality constraints.

The GWO optimizer was being hybridized so that the mutation and crossover were able to be performed. The result has shown that the GWO was able to achieve the objective of the study. used the GWO to find solution to the dynamic economic dispatch (EDP) and solution for no convex of electric power system. The results were then compared to PSO, GA, Biography based optimization (BBO) and Differential Evolution algorithm (DE). It was discovered that the GWO gives better performance. Additionally, the result also revealed that the GWO was able to solve EDP with faster convergence rate. In another study, tested the GWO to solve no convex of the economic dispatch by the transmission loss and the loading effect of the valve point is also being considered. It was found that the GWO in economic dispatch appeared to be the most efficient solution in solving the big scale of the dispatch problem.[21]

3.5 GWO and power system

The hybridization of GWO with pattern search (PS) algorithm in order to prevent power practical against blackout from happening. This is due to the apparition of faults generating units or important transmission lines. During the search process, the target dynamically interacts while best solutions were exchanged between the GWO and PS at some stages. The result indicated that the GWO performed efficiently under critical conditions. the GWO presented the effective method for power losses reduction, gave voltage enhancements and load ability improvements. Recent researches find parameters for automatic generation control (AGC) of primary governor loop by two interconnected power system areas. This method was then differentiated between GSA, PSO and GA. The GWO outperformed standard deviations in parameters value and the objective functions.[21]

3.6 wind energy in the context of smart grid :

Most of the developments in a smart grid have often been identified with its one aspect, smart meters, since they are the most tangible to the common public, customers purchasing the energy. Smart grids promise not only better electricity service and a more reliable power system, but also a cleaner environment and lower cost of power. Renewable energy, such as wind and solar, are often viewed as more expensive alternatives of generating electricity but good for the environment. However, these views do not include the long term benefits of the cleaner renewable energy sources The wind energy in the context of smart grid becomes important due to primarily three factors: economic, environmental, and maturity.

The economy of wind energy is still an ongoing debate. As the wind industry is still in its early stage, the economics are not as optimized as they should be Although the fuel is free, the wind projects come at a cost that is still on the border line with conventional energy sources The environmental aspect of wind energy is clear. No pollution and minimal environmental impact (birds, noise, and aesthetics) make wind one of the most suitable choices of renewable portfolio .[22]

4. Conclusion

Power systems are very large and complex, it can be influenced by many unexpected events this makes Power system optimization problems difficult to solve, hence methods for solving these problems ought to be, an active research topic so we saw, the main objective of optimization is to minimize undesirable things (e.g., cost, energy loss, errors, etc.) or maximize desirable things (e.g., profit, quality, efficiency, etc.) since its mathematical model, subject to some constraints. Optimization is a commonly encountered mathematical problem in all engineering disciplines. It literally means finding the best possible/desirable solution. Optimization problems are wide ranging and numerous, hence methods for solving these problems. From the view of optimization, the various techniques including traditional and modern optimization methods, which have been developed to solve power system operation, control and planning problems

This chapter provided an in-depth literature review and analysis of the GWO algorithm as one of the recent population-based optimizers. Different variants of this algorithm were covered including binary, multi-objective, constrained, and hybridized GWO was applied to several test functions for observing its performance, and in the next chapter we going to see this method how much is effective for challenging the power system problems

Chapter III:

Simulation results

1. Introduction

In this chapter we going to study wind energy solutions from the electrical perspective both present and future, from the smart controls Due to its advantages, many types of research had been carried out for further development of this energy source especially for the integration of wind energy with the smart grid. Hence, the aim of this research is an attempt to focus on grey wolf optimization method and the effect of the wind energy on the total cost.

2. Units system

In order to make a crop for the performance in the 6 units system, the following parameters of each generating units must be taken into account:

- First, the cost coefficients and unit operating limits
- Secondly, Ramp rate limits and prohibited operating zones
- Thirdly, power loss

And that is in both cases: in the absence of wind energy and in its presence where the higher output of wind-powered generator is 200 MW, the proposed algorithm is applied to the test systems, where we take the total load demand as 1263 MW.

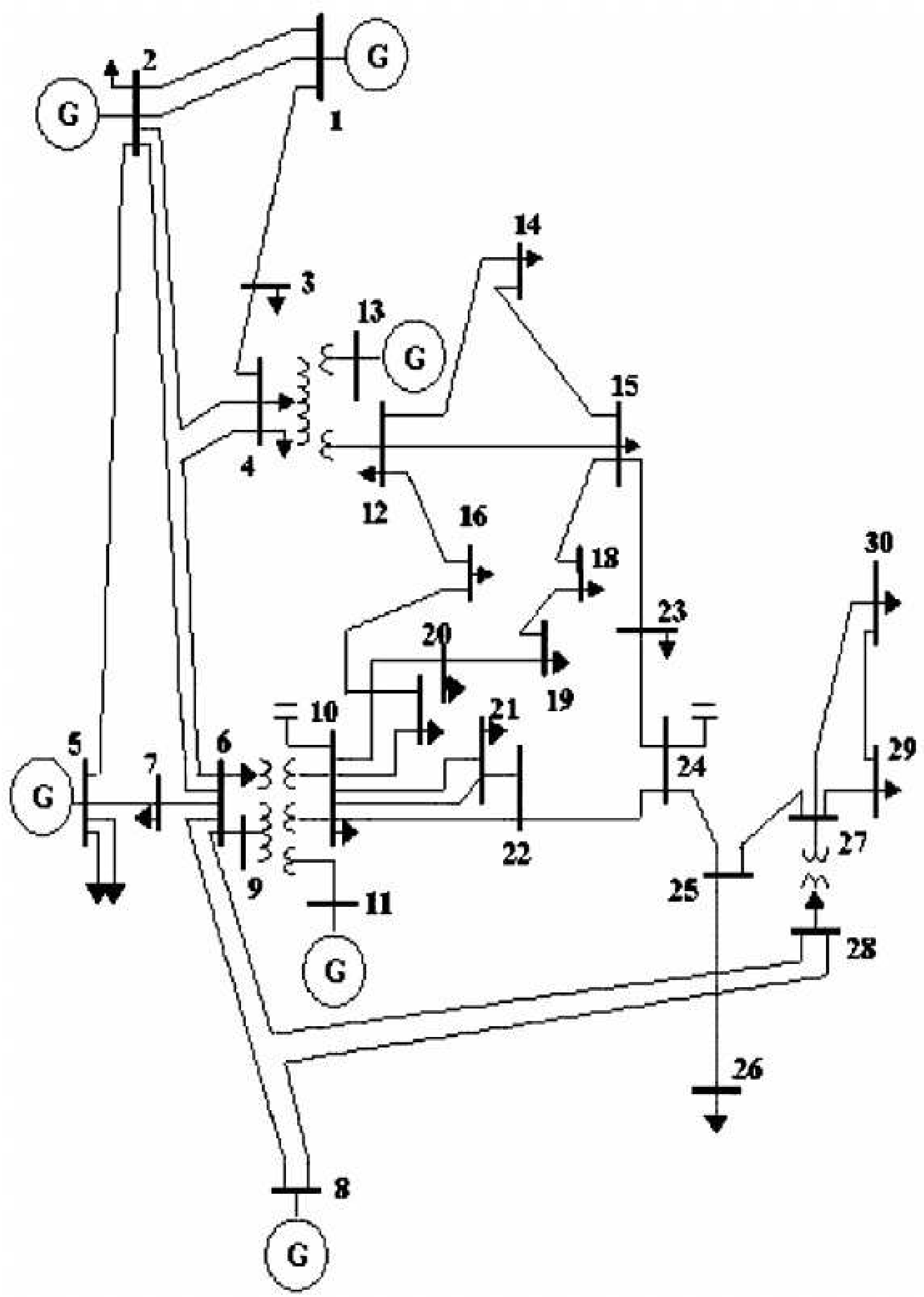


Figure 3.1. Similar scheme of 6units system

2.1 Data

The parameters of all generating units are presented in Table 1 and Table 2 respectively.

Table 3.1: Cost coefficients and unit operating limits

generator	P_i^{min}	P_i^{max}	a	b	c
1	100	500	0.0070	7.0	240
2	50	100	0.0095	10.0	200
3	80	300	0.0090	8.5	220
4	50	150	0.0090	11.0	200
5	50	200	0.0080	10.5	220
6	50	120	0.0075	12.0	190

Table 3.2: Ramp rate limits and prohibited operating zones

Generator	P_i^0(MW)	UR_i (MW/h)	DR_i(MW/h)	Prohibited zone 1 (MW)	Prohibited zones 2 (MW)
1	440	80	120	[210,240]	[350,380]
2	170	50	90	[90,110]	[140,160]
3	200	65	100	[150,170]	[210,240]
4	150	50	90	[80,90]	[110,120]
5	190	50	90	[90,110]	[140,150]
6	150	50	90	[75,85]	[100,105]

The transmission losses are calculated by B matrix loss which for 6 generator system is given as:

B1=

$$\begin{bmatrix} 1.7 & 1.2 & 0.7 & -0.1 & -0.5 & -0.2 \\ 1.2 & 1.4 & 0.9 & 0.1 & -0.6 & -0.1 \\ 0.7 & 0.9 & 3.1 & 0.0 & -1.0 & -0.6 \\ -0.1 & 0.1 & 0.0 & 0.24 & -0.6 & 0.8 \\ -0.5 & -0.6 & -0.1 & -0.6 & 12.9 & -0.2 \\ 0.2 & -0.1 & -0.6 & -0.8 & -0.2 & 15.0 \end{bmatrix}$$

B1=B1*10^-5;

B2= [-0.3908 -0.1297 0.7047 0.0591 0.2161 -0.6635]. * 10^-5;

B3=0.0056*10^-2;

2.2 Results

2.2.1 Without wind

2.2.1.1 Convergence

Table 3.3: Comparison of the best results (without wind) of each n° of iterations (PD = 1263 MW)

N° of iteration	100	200	300	400	500
P1 (MW)	473,8147	484,0631	462,8937	477,4242	500
P2 (MW)	160,5483	182,7605	200	165,3945	200
P3 (MW)	186,7465	203,3922	178,3973	174,3737	190,1021
P4 (MW)	149,4175	95,7718	142,8305	148,6489	103,6995
P5 (MW)	185,2717	197,9917	171,5539	199,3046	164,9729
P6 (MW)	120	113,2301	120	110,9144	107,7994
Total generation (MW)	1275,7987	1277,2094	1275,6754	1276,0603	1266,5739
Total loss (MW)	12.8079	14.2230	12.5698	12.9700	13.3563
Total fuel cost ($/h)	15429.08 35	15428.7936	15426.4972	15423.3199	15400.6745

Through the table, we see that the greater the number of iterations, the closer the method approaches the best solution represented by the lowest possible cost, taking into account all the constrains.

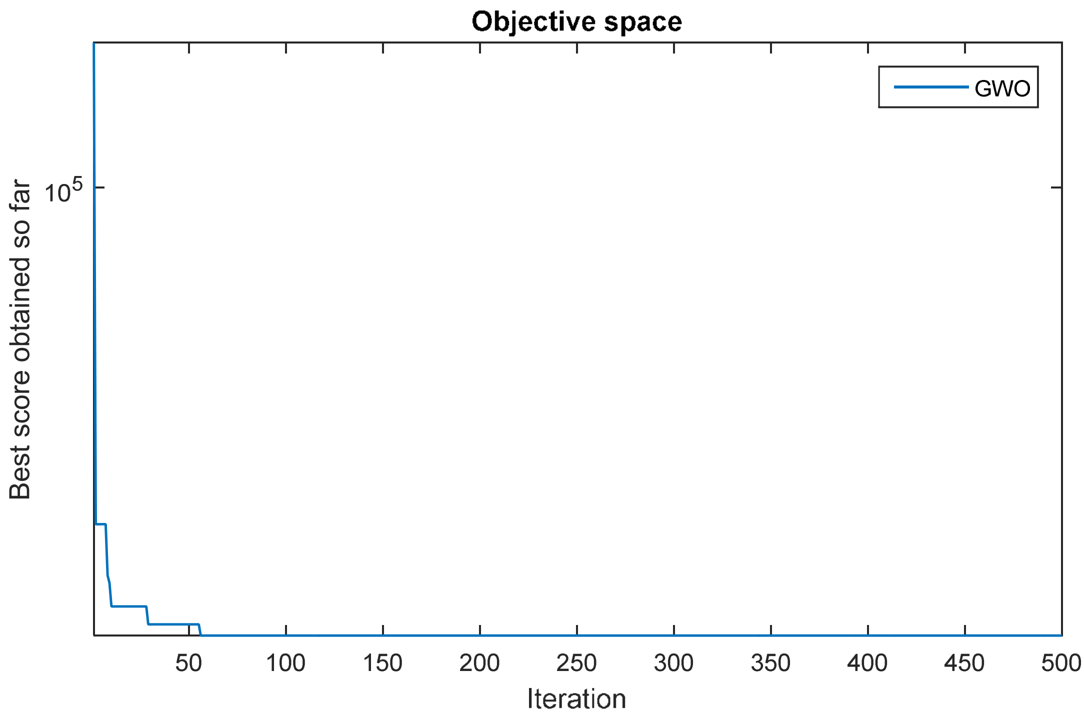


Figure 3.2. Cost convergence characteristic of 6 generator system without wind power (GWO)

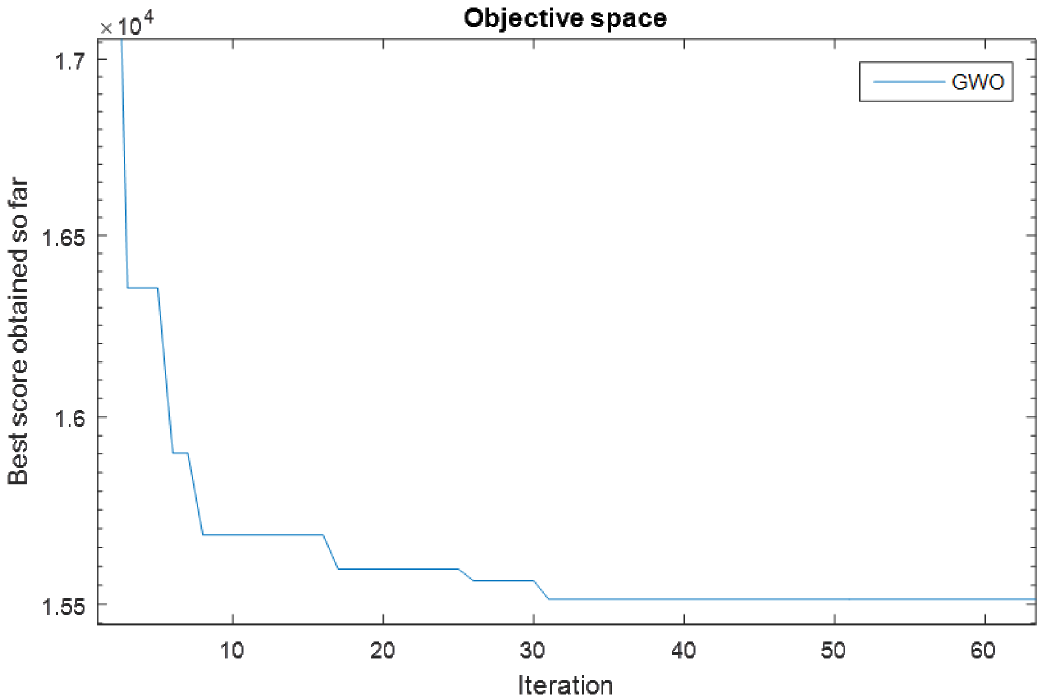


Figure 3.3 Zoom of Cost convergence characteristic of 6 generator system without wind power (GWO)

Through the curve, we notice that the method is close to the optimal solution, starting with 60 iterations, and the result continued to improve until reaching 15400,6745 at 500 iterations, which is the best solution ever.

2.2.1.2 Comparison

Note: for fair comparison we took the results of GWO at 100 iterations to match the results of the other methods.

Table 3.4: Comparison of the best results of each method (PD = 1263 MW)

Unit Output	BBO [14]	CSA [14]	MCSA [14]	GWO
P1 (MW)	447.3997	445.5731	447.3977	473,8147
P2 (MW)	173.2392	172.8935	173.2026	160,5483
P3 (MW)	263.3136	264.4220	263.3661	186,7465
P4 (MW)	138.0060	138.5840	138.9418	149,4175
P5 (MW)	165.4104	166.9367	165.3789	185,2717
P6 (MW)	87.0797	87.0080	87.106	120
Total generation (MW)	1275.4460	1275.4172	1275.3939	1275,7987
Total loss (MW)	12.446	12.4172	12.3939	12.8079
Total fuel cost ($/h)	**15443.09**	**15442.4529**	**15442.3928**	**15429.0835**

The obtained result for 6 generator system using the GWO method is given in Table 3 and the results are compared with other methods reported in literature, including BBO, CSA, MCSA. It can be observed that GWO can get total fuel cost of 15429.08 35 ($/h) and total loss of 12.8079 (MW), which is the best solution among all the methods. Note that the outputs of the generators are all within the generator's permissible output limit.

Note: even when the total generation of GWO method is the highest 1275,7987 (MW),it didn't effect on the fuel cost.

2.2.2 With wind

2.2.2.1 Convergence

The obtained result for 6 generator system using the GWO method is given in Table 3.5 It can be observed that GWO can get the best solution in total cost with wind is 13878.9533 ($/h) and total loss is 12.4696 (MW).

Table 3.5: Comparison of the best results (with wind) of different n° of iterations (PD = 1263 MW)

N° of iterations	100	200	300	400	500
P1 (MW)	468.0700	470.6338	474.7676	480.0000	435.8255
P2 (MW)	176.0534	172.5686	175.7039	174.8068	169.1170
P3 (MW)	109.2599	123.2528	173.6012	165.5954	239.3869
P4 (MW)	127.9782	126.6811	122.3067	107.2051	119.9489
P5 (MW)	174.1303	165.6881	107.9701	139.7820	138.5548
P6 (MW)	99.6347	91.0023	100.000	88.4721	52.5438
P Wind (MW)	119.9939	119.9975	120.0294	119.977	119.9947
Total generation (MW)	1156.1265	1155.8971	1155.3495	1155.8614	1155.4749
Total loss (MW)	13.1204	12.8946	12.37	12.8387	12.4696
Total fuel cost ($/h)	**14086.8185**	**14043.1912**	**13993.3755**	**13985.3064**	**13878.9533**

We noted that when we augmented on number of iterations, we get the minimum of cost.

The cost convergence characteristic of 6 generator system obtained from GWO is shown in Figure 3.2 its noticed that GWO leads to lowest fuel cost (14086.8185). Good convergences characteristic are achieved using the proposed GWO.

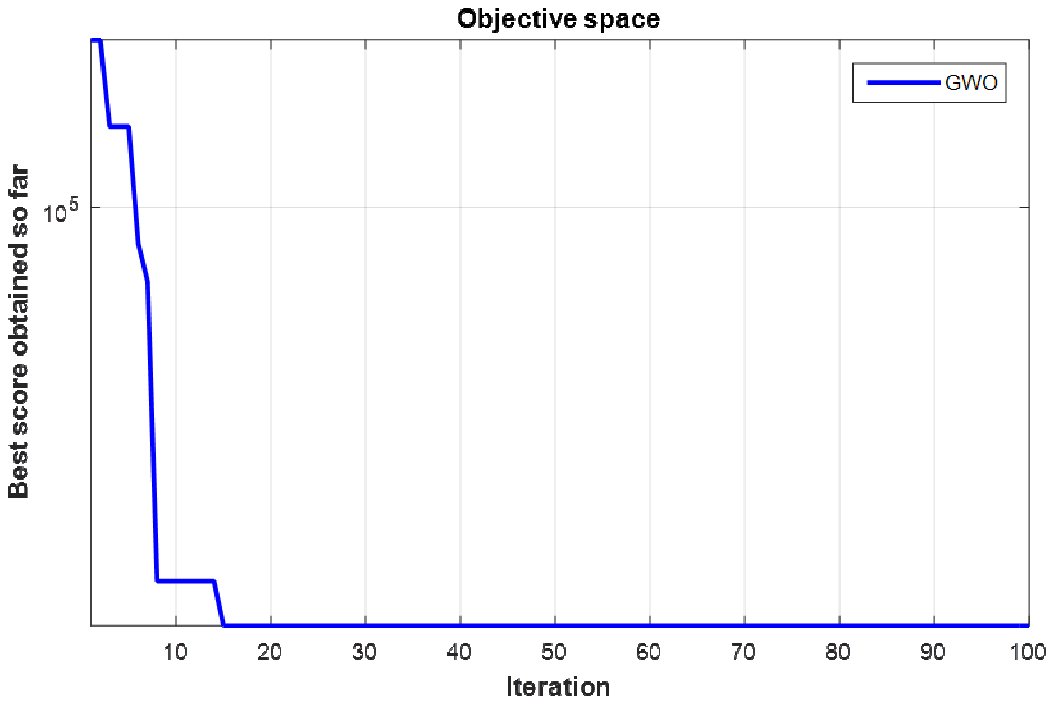


Figure 3.4: Cost convergence characteristic of 6-generator system with wind power (GWO)

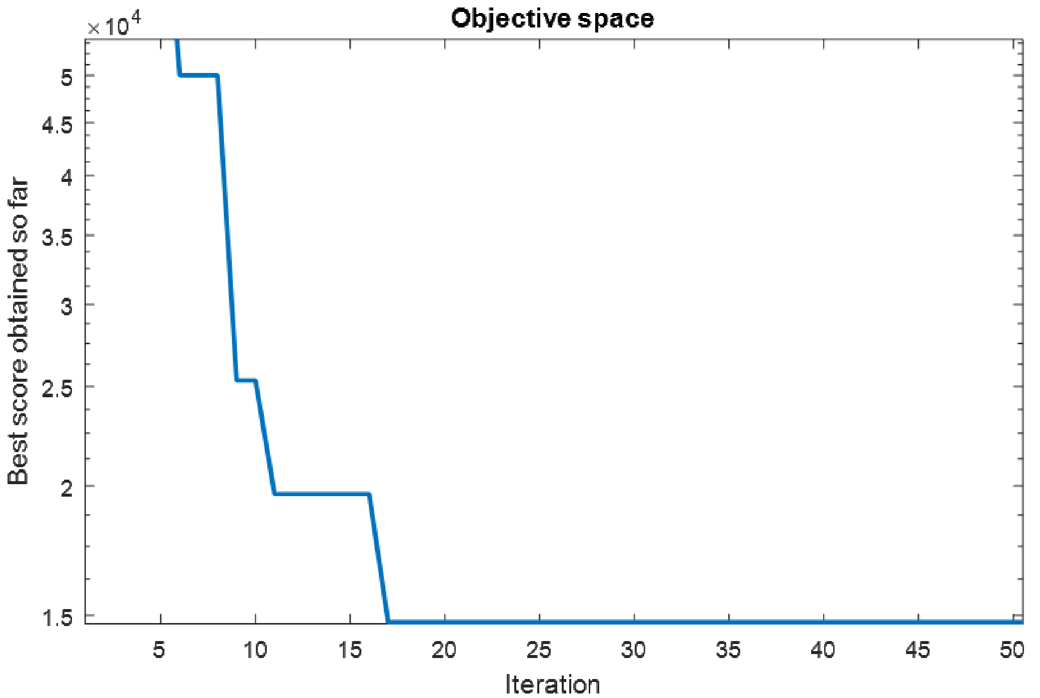


Figure 3.5 Zoom of Cost convergence characteristic of 6-generator system with wind power (GWO)

The results obtained show that GWO have been successfully implemented to solve different EDP besides GWO is able to provide very competitive results in terms of minimizing total fuel cost and lower transmission loss. It has been observed that the GWO has the ability to converge to a better quality near-optimal solution and possesses better convergence characteristics than other prevailing techniques.

8.1.1.1 2.2.2.2 Comparison

In Table 3.6, EDP is carried out by considering thermal as well as wind power simultaneously. From the Table 3.4, it is understood that the cost and transmission losses are significantly reduced with the integration of wind power in to the system. The cost convergence characteristic of 6-generator system with wind power is given in Figure 3.3.[14]

Note: for fair comparison we took the results of GWO at 100 iterations to match the results of the other methods.

Table 3.6: Simulation results for 6-generator system with and without wind power using GWO

Unit Output	GWO	MCSA [14]
P1 (MW)	468.0700	443.4757
P2 (MW)	176.0534	170.2548
P3 (MW)	109.2599	259.4349
P4 (MW)	127.9782	136.2384
P5 (MW)	174.1303	161.0422
P6 (MW)	99.6347	83.9991
Total generation (MW)	1156.1265	1254.4452
P Wind (MW)	119.9939	20.5451
Total loss (MW)	13.1204	11.9903
Total fuel Cost ($/h)	14086.8185	15205.9913

3. Units system

After making sure of the effectiveness of the grey wolf optimization method in 6 units System, we repeat the same experiment on a larger network (15 units System with PD=2630 MW) to see its effectiveness at the level of convergence and economic dispatch (minimizing cost). As well as to determine the role of the wind power and its rate of penetration on the total generation, where all constrains must be taken into account.

3.1Data

The following parameters of each generating units must be taken into account:

- First, the cost coefficients and unit operating limits in table 3.7
- Secondly, Ramp rate limits and prohibited operating zones in table 3.8
- Thirdly, power loss

Table 3.7: Cost coefficients and unit operating limits

generator	Pmin	Pmax	a	b	c
1	150	455	0.000299	10.1	671
2	150	455	0.000183	10.2	574
3	20	130	0.001126	8.8	374
4	20	130	0.001126	8.8	374
5	150	470	0.000205	10.4	461
6	135	460	0.000301	10.1	630
7	135	465	0.000364	9.8	548
8	60	300	0.000338	11.2	227
9	25	162	0.000807	11.2	173
10	25	160	0.001203	10.7	175
11	20	80	0.003586	10.2	186

12	20	80	0.005513	9.9	230
13	25	85	0.000371	13.1	225
14	15	55	0.001929	12.1	309
15	15	55	0.004447	12.4	323

Table 3.8: Ramp rate limits and prohibited operating zones

Generator	P0	UR	DR	Prohibited zone 1	Prohibited zone 2	Prohibited zone 3
1	400	80	120	[150-150]	[150-150]	[150-150]
2	300	80	120	[185-225]	[305-335]	[420-450]
3	105	130	130	[20-20]	[20-20]	[20-20]
4	100	130	130	[20-20]	[20-20]	[20-20]
5	90	80	120	[180-200]	[305-335]	[390-420]
6	400	80	120	[230-255]	[365-395]	[430-455]
7	350	80	120	[135-135]	[135-135]	[135-135]
8	95	65	100	[60-60]	[60-60]	[60-60]
9	105	60	100	[25-25]	[25-25]	[25-25]
10	110	60	100	[25-25]	[25-25]	[25-25]
11	60	80	80	[20-20]	[20-20]	[20-20]
12	40	80	80	[30-40]	[55-65]	[20-20]
13	30	80	80	[25-25]	[25-25]	[25-25]
14	20	55	55	[15-15]	[15-15]	[15-15]
15	20	55	55	[15-15]	[15-15]	[15-15]

Power loss

B1=

$$\begin{bmatrix} 1.4 & 1.2 & 0.7 & -0.1 & -0.3 & -0.1 & -0.1 & -0.1 & -0.3 & -0.5 & -0.3 & -0.2 & 0.4 & 0.3 & -0.1 \\ 1.2 & 1.5 & 1.3 & 0.0 & -0.5 & -0.2 & 0.0 & 0.1 & -0.2 & -0.4 & -0.4 & 0.0 & 0.4 & 1 & -0.2 \\ 0.7 & 1.3 & 7.6 & -0.1 & -1.3 & -0.9 & -0.1 & 0.0 & -0.8 & -1.2 & -1.7 & -0.0 & -2.6 & 11.1 & -2.8 \\ -0.1 & 0.0 & -0.1 & 3.4 & -0.7 & -0.4 & 1.1 & 5.0 & 2.9 & 3.2 & -1.1 & 0.0 & 0.1 & 0.1 & -2.6 \\ -0.3 & -0.5 & -1.3 & -0.7 & 9.0 & 1.4 & -0.3 & -1.2 & -1.0 & -1.3 & 0.7 & -0.2 & -0.2 & -2.4 & -0.3 \\ -0.1 & -0.2 & -0.9 & -0.4 & 1.4 & 1.6 & 0.0 & -0.6 & -0.5 & -0.8 & 1.1 & -0.1 & -0.2 & -1.7 & 0.3 \\ -0.1 & 0.0 & -0.1 & 1.1 & -0.3 & 0.0 & 1.5 & 1.7 & 1.5 & 0.9 & -0.5 & 0.7 & 0.0 & -0.2 & -0.8 \\ -0.1 & 0.1 & 0.0 & 5.0 & -1.2 & -0.6 & 1.7 & 16.8 & 8.2 & 7.9 & -2.3 & -3.6 & 0.1 & 0.5 & -7.8 \\ -0.3 & -0.2 & -0.8 & 2.9 & -1.0 & -0.5 & 1.5 & 8.2 & 12.9 & 11.6 & -2.1 & -2.5 & 0.7 & -1.2 & -7.2 \\ -0.5 & -0.4 & -1.2 & 3.2 & -1.3 & -0.8 & 0.9 & 7.9 & 11.6 & 20.0 & -2.7 & -3.4 & 0.9 & -1.1 & -8.8 \\ -0.3 & -0.4 & -1.7 & -1.1 & 0.7 & 1.1 & -0.5 & -2.3 & -2.1 & -2.7 & 14.0 & 0.1 & 0.4 & -3.8 & 16.8 \\ -0.2 & 0.0 & 0.0 & 0.0 & -0.2 & -0.1 & 0.7 & -3.6 & -2.5 & -3.4 & 0.1 & 5.4 & -0.1 & -0.4 & 2.8 \\ 0.4 & 0.4 & -2.6 & 0.1 & -0.2 & -0.2 & 0.0 & 0.1 & 0.7 & 0.9 & 0.4 & -0.1 & 10.3 & -10.1 & 2.8 \\ 0.3 & 1.0 & 11.1 & 0.1 & -2.4 & -1.7 & -0.2 & -0.5 & 1.2 & -1.1 & -3.8 & -0.4 & -10.1 & 57.8 & -9.4 \\ -0.1 & -0.2 & -2.8 & -2.6 & -0.3 & 0.3 & -0.8 & -7.8 & -7.2 & -8.8 & 16.8 & 2.8 & 2.8 & -9.4 & 128.3 \end{bmatrix}$$

B1=B1.*0;

B2=[-0.1 -0.2 2.8 -0.1 0.1 -0.3 -0.2 -0.2 0.6 3.9 -1.7 0.0 -3.2 6.7 -6.4].*0;

B3=0.0*10^-2;

3.2 Results

3.2.1 Without wind

3.2.1.1 Convergence

Table 3.9: Comparison of the best results (without wind) of each n° of iterations (PD = 2630 MW)

N° of iterations	100	200	300	400	500
P1	455	442.9971	455	423.0212	443.6751
P2	366.2727	343.9190	363.6933	352.3304	339.0521
P3	130	126.3609	126.0536	120.5233	129.6950
P4	130	122.0706	130	130	129.7404
P5	200.4152	202.9618	204.2252	184	183
P6	460	460	460	455.2005	450
P7	364.3150	422.1761	365.1728	411.3578	419.5973
P8	156.9288	135.5425	132.1070	109.6303	95.2390

P9	87.6188	43.4953	28.2506	132.7808	92.4805
P10	108.7165	154.0641	156.1102	159.0790	155.4681
P11	46.7448	41.5023	43.0359	80	76.5602
P12	75.0772	77.5370	80	21.8283	35.7619
P13	33.8411	33.3044	67.8644	27.1557	40.3384
P14	20.3924	24.9164	46.4740	36.0333	32.4521
P15	36.6940	40.1112	41.0279	22.0362	30.9478
Total generation (MW)	2 672,0165	2 670,9542	2670.7647	2 664,9768	2 664,0079
Total loss (MW)	42.0165	40.9542	40.7647	34.9768	34.0079
Total fuel cost ($/h)	**3.2549**	**3.2533**	**32525**	**3.2521**	**3.2517**

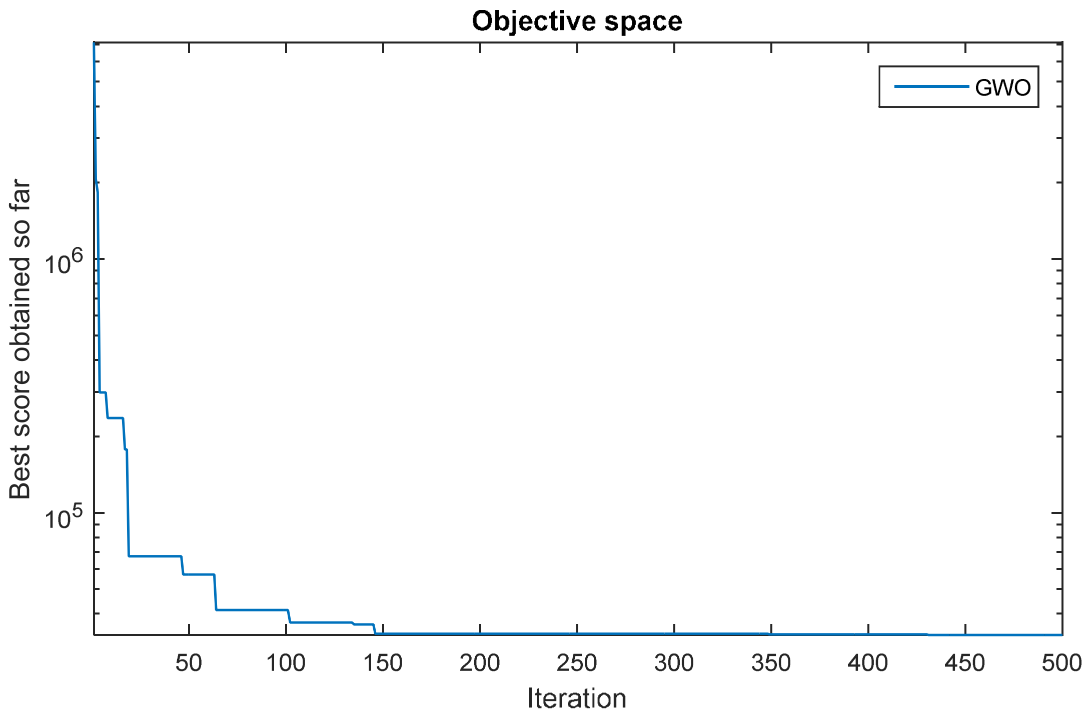


Figure 3.6: Cost convergence characteristic of 15 generator system without wind power (GWO)

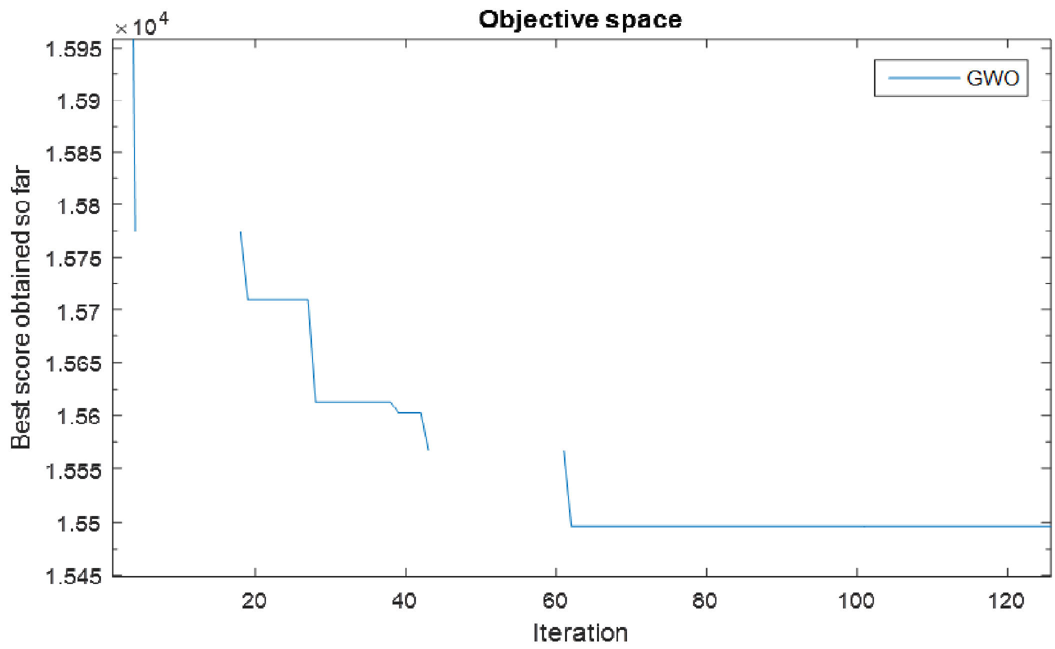


Figure 3.7 Zoom of Cost convergence characteristic of 15 generator system without wind power (GWO)

3.2.1.2 Interpretation

According the table 9 and after an increase in the number of iterations. We notice a slight improvement of the total fuel cost.

After observing this curve; we find that the generators took between [150-350] iterations to find the optimal solution which means we have a significant response time.

And we note that between [0-50] There is a large gap in the improvement of the result; while between [50-100] We notice a rapid improvement in convergence of reaching the best result.

3.2.3With wind

3.2.2.1Convergence

Table 3.10: Comparison of the best results (with wind) of each n° of iterations (PD = 2630 MW)

N° of iterations	100	200	300	400	500
P1 (MW)	434.2277	411.0000	424.5979	412.1109	423.6615
P2 (MW)	348.7886	336.1157	323.3982	336.5394	328.0308
P3 (MW)	96.5292	102.4641	93.2325	102.6091	106.5557
P4 (MW)	105.9723	108.1190	107.4950	103.6963	109.7124
P5 (MW)	130	137.6943	130.0000	134.7725	131.1050
P6 (MW)	435.0054	439.8460	440.0000	438.5053	440.0000
P7(MW	395.7055	377.6078	363.2569	397.1183	374.8430
P8(MW)	62.6828	114.3123	129.1480	80.0031	130.0354
P9(MW)	129.8773	101.5170	36.7448	128.9682	35.2475
P10(MW)	100.0324	84.6084	140.0000	25.0731	138.9786
P11(MW)	37.0765	17.2176	56.9633	33.8584	47.6943
P12(MW)	21.2833	22.6219	57.4286	58.7566	22.6592
P13(MW)	15.7646	56.8799	8.1431	61.9209	42.1302
P14(MW)	35.0000	31.7108	27.4836	31.8805	23.5492
P15(MW)	16.0853	16.0460	26.7518	14.0277	16.4066
Total generation (MW)	2364.0309	2365.7608	2364.6437	2359.8403	2370.6094
P Wind (MW)	300.2009	299.9823	299.929	300.0116	300.0138
TotaL loss (MW)	34.2318	35.7431	34.5727	34.8519	35.6232
Total fuel cost ($/h)	**29932.3109**	**29844.9595**	**29807.3375**	**29795.9814**	**29792.0263**

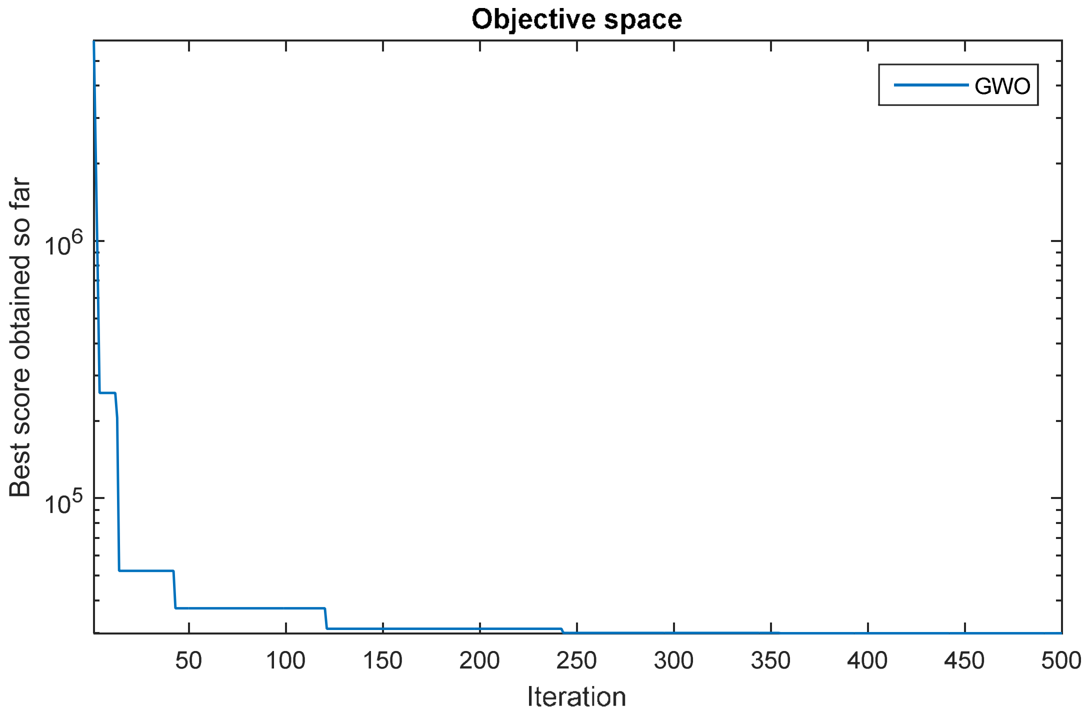


Figure 3.8: Cost convergence characteristic of 15 generator system with wind power (GWO)

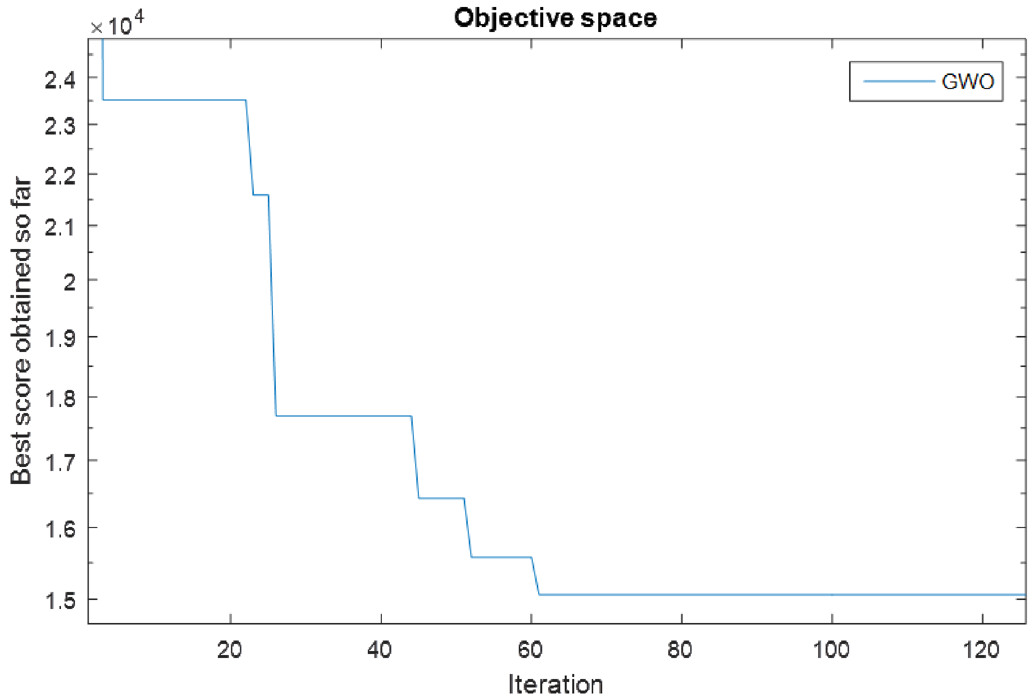


Figure 3-9 Zoom of Cost convergence characteristic of 15 generator system with wind power (GWO)

Through the table and the curve, we find that there is a direct relationship between the convergence of the cost and the number of iterations, where the greater the number of iterations, the better cost we get.

We also note that at [0.40] the method was in huge divergence, which led to a high cost, while [40,120] the method began to converge, but in a weak way. Between [120,140] approximately, the convergence was made to the optimal solution. A small percentage of the error remains that can be considered invisible, while [240,500] The convergence was completely achieved, as the optimal cost reached **29792.0269($/h).**

For generators, we find that GWO reduce pressure on high-power generators, but their working range remains close to the max, such as P1.

While the medium power generators Gray Wolf select the low-priced generators and increase their power such as P8. The same is with the weak power generators, except that most of them work close to their lower power range such as P15, P14 and P12.

Note: due to the inability to control the wind power generator (the wind power is relatively unstable), the Gray Wolf takes time to converge to the best solution, between 120 and 240 iterations

3.2.2.2 Comparison

Table 3.11: Simulation results for 15 units system with and without wind power using GWO (PD = 2630MW)

Unit Output	GWO	
	Withwind	Withoutwind
P1 (MW)	423.6615	443.6751
P2 (MW)	328.0308	339.0521
P3 (MW)	106.5557	129.6950
P4 (MW)	109.7124	129.7404
P5 (MW)	131.1050	183
P6 (MW)	440.0000	450
P7(MW)	374.8430	419.5973
P8 (MW)	130.0354	95.2390
P9 (MW)	35.2475	92.4805
P10(MW)	138.9786	155.4681
P11 (MW)	47.6943	76.5602
P12 (MW)	22.6592	35.7619

P13 (MW)	42.1302	40.3384
P14 (MW)	23.5492	32.4521
P15 (MW)	16.4066	30.9478
P wind (MW)	300.01380000	/
Total generation (MW)	2370.60940000	2 664,0079
Total loss (MW)	35.62320000	34.0079
Total fuel cost ($/h)	**29792.0263**	**32517**

Through ''Simulation results for 15 units system with and without wind power using GWO (PD = 2630MW)''Table we find that in the presence of the wind, the power was reduced in all the generators, as the generators)1,2,3,4,6,10 and 11(, their rate of decrease was about (20 MW), while generators (5,7,9) decreased by (30MW), while generators (12,14,15) decreased by less than (15MW), only generators 8 and 13 have an incensement in power.

Note: Wind contributed to reducing the production price by 8.4%, when producing only 300 (MW) with a penetration rate of 15%, Gray Wolf tried to reduce the production of medium and small generators (working in complete comfort), while the effect of the wind power on large generators was small.

3.2.2.3 Wind penetration rate:

Table 3.12: Simulation results for 15 units system with wind power using GWO in different penetration rate (PD = 2630MW)

Unit Output	**Wind penetration rate**		
	15%	**20%**	**25%**
P1 (MW)	423.6615	402.2334	411.4488
P2 (MW)	328.0308	317.3069	336.2775
P3 (MW)	106.5557	84.1274	92.9946
P4 (MW)	109.7124	89.7767	96.2335
P5 (MW)	131.1050	125.9682	134.8137
P6 (MW)	440.0000	379.8686	384.9623
P7(MW)	374.8430	352.5764	383.1503
P8 (MW)	130.0354	103.7961	90.2381
P9 (MW)	35.2475	128.1346	37.4634

P10(MW)	138.9786	111.1811	113.6033
P11 (MW)	47.6943	53.3551	16.8380
P12 (MW)	22.6592	46.5142	41.8818
P13 (MW)	42.1302	46.3950	18.0182
P14 (MW)	23.5492	18.7177	21.8853
P15 (MW)	16.4066	16.9116	16.7851
P wind (MW)	300.0138	390.0286	469.8656
Total generation (MW)	2370.6094	2276.863	2193.9179
Total loss (MW)	35.6232	36.8916	33.9607
Total fuel cost ($/h)	**29792.0263**	**28965.7286**	**27796.8541**

From the table 12 we find that the higher the wind power, the lower the total generation, resulting in a lower cost, which was 29,792 at 15%, decreased to 28,965 at 20%, and decreased further at 25%, reaching 27796, and that is, the greater the penetration, the more the generators work at rest stat ensuring the best economic performance.

4. Conclusion

In this chapter, the grey wolf optimizer (GWO) algorithm has been presented and applied to the total cost function of a system consisting of several power generation units (6 generators) and (15generators) The study proves the efficiency of renewable energies and its positive impact on modern power grid management.

Thus, we have concluded that the integration of renewable energies has a positive impact on the economic distribution, which will considerably reduce the losses of money compared to the traditional system, the results obtained in the studied case say that the addition of wind turbines reduce the fuel consumption and has a more favorable economic impact than the classic one.

This study applied the new method grey wolf optimizer (GWO) to solve the optimal power flow the main objective of the optimization problem is to minimize the system total cost. The results showed that the method gives a better performance with optimal results in all cases and within the constraints imposed.

General conclusion

We conclude with the efficiency of smart grid which represent an unprecedented opportunity to move the energy industry into a new era of reliability, availability, and efficiency that will contribute to our economic and environmental health. During the transition period, it will be critical to carry out testing, technology improvements, consumer education, development of standards and regulations, and information sharing between projects to ensure that the benefits we envision from the Smart Grid become a reality. The benefits associated with the Smart Grid include:

- More efficient transmission of electricity
- Quicker restoration of electricity after power disturbances
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers
- Reduced peak demand, which will also help lower electricity rates
- Increased integration of large-scale renewable energy systems
- Better integration of customer-owner power generation systems, including renewable energy systems
- Improved security [23]

Also, we note the advanced wind energy technology, paired with commercially available grid management systems, power electronics, enhanced medium voltage switchgears for wind farm application, grid interconnection solutions, cable technologies, and with Energy Storage can enable an efficient, reliable and environmentally-friendly smarter grid operation. A cost-effective wind energy production and delivery system can be implemented with a systematic approach and end-to-end design. These enhancements result in a smart grid that is an adaptive, integrated, and optimized electricity generation and delivery system, benefiting both consumers and the eco system [24]

We must also mention the importance of the correct choice of the method of calculation due to the effectiveness of the theory. We get good results compared to other theories, although they are new and not used much in the field of electrical research

Recommendations for future research

Beyond this work and the satisfactory results obtained, there are still some. Issues that could be the subject of effort and investment through the study and Treatment of the following points.

- Relying on various renewable sources and increasing their penetration rates in smart grids.
- Attempting to hybrid several optimization methods with GWO to solve the problem of economic dispatch.
- The use of other programming languages such as PYTHON, or C language or C++ language in object-oriented programming, in order to better decide on time execution of the programs and to be able to better conclude on the speed of convergence of each of the techniques studied, which is difficult to do with the Matlab language.

.

Bibliography

Bibliography

[1] "What is a Smart Grid? - Definition from Techopedia." https://www.techopedia.com /definition /692/smart-grid (accessed Jun. 23, 2022).

[2] "Architecture Smart Grids : vers des réseaux électriques flexibles et communicants." https://www.linkedin.com/pulse/architecture-smart-grids-vers-des-r%C3%A9seaux-%C3%A9lectriques-safaa-benghrib/ (accessed Jun. 23, 2022).

[3] "Architecture Smart Grids : vers des réseaux électriques flexibles et communicants." https://www.linkedin.com/pulse/architecture-smart-grids-vers-des-r%C3%A9seaux-%C3%A9lectriques-safaa-benghrib?articleId=6257927077182341120 (accessed Jun. 27, 2022).

[4] "Commande à base de descripteurs flous d'une architecture de génération distribuée." https://www.ummto.dz/dspace/handle/ummto/1642?locale-attribute=en (accessed Jun. 27, 2022).

[5] "Renewable Energy Definition and Types of Renewable Energy Sources | NRDC." https://www.nrdc.org/stories/renewable-energy-clean-facts (accessed Jun. 27, 2022).

[6] J. Yuryevich, "Evolutionary programming based optimal power flow algorithm," *IEEE Transactions on Power Systems*, vol. 14, no. 4, pp. 1245–1250, 1999, doi: 10.1109/ 59. 801880.

[7] "Smart Grids and Renewables: A cost-benefit analysis guide for developing countries." https://irena.org/publications/2015/Oct/Smart-Grids-and-Renewables-A-cost-benefit-analysis-guide-for-developing-countries (accessed Jun. 27, 2022).

[8] S. Paul, M. Siddikur Rahman, A. Rahman, and M. haqueshahed, "Wind Energy Integration in Smart Grid," *International Journal of Scientific & Engineering Research*, vol. 5, no. 11, 2014, Accessed: Jun. 27, 2022. [Online]. Available: http://www.ijser.org

[9] F. Ayadi, I. Colak, I. Garip, and H. I. Bulbul, "Impacts of Renewable Energy Resources in Smart Grid," *8th International Conference on Smart Grid, icSmartGrid 2020*, pp. 183–188, Jun. 2020, doi: 10.1109/ICSMARTGRID49881.2020.9144695.

[10] P. Geoffron, "4. L'économie des smart-grids," *L'énergie à découvert*, pp. 282–283, Oct. 2013, doi: 10.4000/BOOKS.EDITIONSCNRS.11185.

[11] "Résolution de Dispatching Optimal en Combinant l'Ecoulement de Puissance pour le Calcul des Pertes | Semantic Scholar." https://www.semanticscholar.org/paper/R%C3% A9solution-de-Dispatching-Optimal-en-Combinant-de-Belhachem-Benhamida/e1c9921ffe1cb2b67fcadafbf461e680798eacce (accessed Jun. 27, 2022).

[12] "(2) (PDF) Répartition optimale des puissances actives par les méthodes Hessiennes." https://www.researchgate.net/publication/238732752_Repartition_optimale_des_puissances_actives_par_les_methodes_Hessiennes (accessed Jun. 27, 2022).

[13] L. Imen, L. Djamel, S. Hassiba, D. Abdellah, and F. Selwa, "Optimal power flow study using conventional and neural networks methods," *2015 International Conference on Renewable Energy Research and Applications, ICRERA 2015*, pp. 1422–1427, 2015, doi: 10.1109/ICRERA.2015.7418642.

[14] Economic Dispatch of Wind-Thermal Power System using Modified Cuckoo Search AlgorithmM. Iqbal Arsyad, Fitriah, Hardiansyah/ https://www.researchgate.net/ publication /359437894

[15] PuneetGhanghas /Optimization/ academia.edu/4610425/Optimization

[16] https://www.merriam-webster.com/ Optimization." Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam webster.com/dictionary/optimization. Accessed 17 Jun. 2022

[17] ME256 Indian Institute of Science;Variational Methods and Structural Optimization /G. K. Ananthasuresh Professor, Mechanical Engineering

[18] I. Boussaïd, J. Lepagnot, and P. Siarry, "A survey on optimization metaheuristics," Information Sciences, vol. 237, pp. 82–117, Jul. 2013, doi: 10.1016/J.INS.2013.02.041.

[19] Amit Shewale ; Anil Mokhade ; Nitesh Funde ; Neeraj Dhanraj Bokde / A Survey of Efficient Demand-Side Management Techniques for the Residential Appliance Scheduling Problem in Smart Homes; Received: 28 February 2022 / Revised: 5 April 2022 / Accepted: 9 April 2022 / Published: 14 April 2022/

[20] Ashfaq ahmed ;Nadeem Javaid ; umarqasim ; Zahoor ali khan / www.nJavaid.com, NadeemJavaid@cosmats.edu.pk.nadeem.javaid@univ-paris12.fr / demand response:from

[21] N. M. Hatta, A. M. Zain, R. Sallehuddin, Z. Shayfull, and Y. Yusoff, "Recent studies on optimisation method of Grey Wolf Optimiser (GWO): a review (2014–2017)," Artificial Intelligence Review 2018 52:4, vol. 52, no. 4, pp. 2651–2683, May 2018, doi: 10.1007/S10462-018-9634-2.

[22] Glinkowski, M.; Hou, J.; Rackliffe, G. (2011). Advances in Wind Energy Technologies in the Context of Smart Grid

[23] "Grey Wolf Optimizer | Advances in Engineering Software | onAcademic." https://www.onacademic.com/detail/journal_1000036039888810_73bd.html (accessed Jun. 24, 2022).

[24] "Office of Electricity | Department of Energy." https://www.energy.gov/oe/office-electricity (accessed Jun. 24, 2022).