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Whale Optimization Algorithm for Renewable Resources Using 33-Bus System

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***Abstract*: Distributed generator (DG) resources are the emerging micro-generating technologies such as fuel cells, micro turbines, IC engines. They also make use of renewable energy sources such as PV arrays and Wind Turbines. DG units have low emission rates and are environment friendly and economical. Power loss reductions, voltage profile improvement and increasing reliability are some advantages of DG units. The above benefits can be achieved by optimal placement of DGs. Optimal DG locations are obtained from power loss index method. A novel metaheuristic algorithm called Whale Optimization Algorithm (WOA) is used to determine the optimal DG-units size in this paper. WOA modeled based on the unique hunting behavior of humpback whales. The WOA algorithm is tested on IEEE 33-bus test systems. The results obtained by the proposed WOA algorithm were compared with different types of DGs and other evolutionary algorithms. When compared with other algorithms the WOA algorithm gives better results.**

Index Terms: Whale Optimization Algorithm (WOA, Distributed generator (DG), PV arrays and Wind Turbines

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INTRODUCTION

Hybrid energy system is the combination of two energy sources for giving power to the load. In other word it can defined as "Energy system which is fabricated or designed to extract power by using two energy sources is called as the hybrid energy system." Hybrid energy system has good reliability, efficiency, less emission, and lower cost. Wherever continuous and discrete dynamics interact, hybrid systems arise. This is especially profound in many technological systems, in which logic decision making and embedded control actions are combined with continuous physical processes. To capture the evolution of these systems, mathematical models are needed that combine in one way or another dynamics of the continuous parts of the system with the dynamics of the logic and discrete parts. These mathematical models come in all kinds of variations, but basically consist of some form of differential or difference equations on the one hand and automata or other discrete-event models on the other hand. The collection of analysis and synthesis techniques based on these models forms the research area of hybrid systems theory, which plays an important role in the multi-disciplinary design of many technological systems that surround us. The modern power distribution network is constantly being faced with a very rapid growing load demand, this increasing load is resulting into increased burden and reduced voltage also effect on the operation, planning, technical and safety issues of distribution networks.

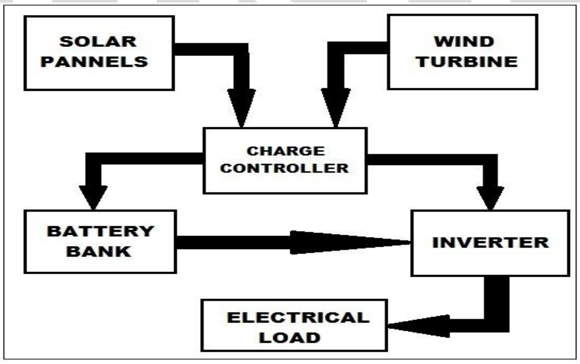

Fig. 1 Hybrid System

I. Solar System

Solar energy is that energy which is gets by the radiation of the sun. Solar energy is present on the earth continuously and in abundant manner. Solar energy is freely available. It doesn't produce any gases that mean it is pollution free. It is affordable in cost. It has low maintenance cost. Only problem with solar system it cannot produce energy in bad weather condition. But it has greater efficiency than other energy sources. It only need initial investment. It has long life span and has lower emission.

II. Wind System

Wind energy is the energy which is extracted from wind. For extraction we use wind mill. Ii is renewable energy sources. The wind energy needs less cost for generation of electricity. Maintenance cost is also less for wind energy system. Wind energy is present almost 24 hours of the day. It has less emission. Initial cost is also less of the system. Generation of electricity from wind is depend upon the speed of wind flowing. The major disadvantages of using independent renewable energy resources are that unavailability of power for all time. For overcoming this we use solar and wind energy together. So that any one source of power fails other will take care of the generation. In this proposed system we can use both sources combine. Another way is that we can use any one source and keep another source as a stand by unit. This will leads to continuity of generation. This will make system reliable.

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III. Distribution System

Classically, most distribution systems (DSs) are radial in nature, contain only one power source, and serve residential, commercial and industrial loads. DSs are also operated at the lowest voltage levels in the overall power networks. Power is delivered in bulk to substations. The substation is usually where the transmission and distribution networks meet. The backbone of the distribution networks typically is comprised of 3-phase mains. Laterals are tapped off these mains and are usually single-phase (unless 3-phase service is required by a customer). In addition, the lines used for DSs tend to have a higher resistance to impedance ratio (R/X) than the lines in transmission networks. The modern power distribution network is constantly being faced with a very rapid growing load demand, this increasing load is resulting into increased burden and reduced voltage also effect on the operation, planning, technical and safety issues of distribution networks.

These power losses in distribution networks have become the most concerned issue in power losses analysis in any power networks. In the effort of reducing power losses within distribution networks, reactive power compensation has become increasingly important as it affects the operational, economical and quality of service for electric power networks. The proposed models are grouped in a three-level classification structure starting with two broad categories, i.e., planning without and with reliability considerations. Planning of a distribution system relies on upon the load flow study.

SOLAR PV AND WIND SYSTEM

I. Solar PV System

The sun is the largest energy source of life at the same time, it is the ultimate source of all energy (except power of geothermal). The sun radiates 174 trillion kWh of energy to the earth per hour. In other words, the earth receives 1.74 x 10 17 watts of power from the sun. Characteristics of the sun is simplified as follows : mass 2×10^{30} kg, beam length 700.000 km, age 5×10^{9} years and estimated roughly 5 billion more years of life. The surface temperature of sun is approximately 5800 K while the internal temperature is approximately 15.000.000 K. High temperature reactions is due to the transformation of hydrogen in helium. The process of the nuclear fusion, which is characterized from the following reaction 4 H→4He+ Energy, is the result of the sun high temperature and the large amounts of energy emitted continuously. It is calculated that for each gram of hydrogen, that is converted to He, sun radiates energy equal with U= 1.67×10^{5} kWh. The solar energy is emitted to the universe mainly by electromagnetic radiation. The estimated distance from the sun is 150,000,000 km while the sun is stationed and spins around by the earth in an elliptic orbit. The light having the travelling speed of 300,000 km/sec to overcome the aforesaid distance, it consumed approximately 8.5 minutes. Actinic of emitted radiation is removed by the aster to the space and the intensity of radiation J, is calculated by the equation below:

$$J = \frac{P}{4\pi d^2}$$

`P' *is presenting the electromagnetic radiation power and*

`d*' is presenting the distance from the sun.*

It is estimated that one-third of the radiation is reflected back. The rest of energy will be absorbed and retransmitted to the space while the earth reradiates just as energy as it receives and creates a balance of energy balance at the level of temperature which is suitable for life. Solar energy can be used to generate electricity directly with the photovoltaic panels.

II. Photovoltaic Structure

First of all, the efficiency of photons absorption is increasing due to the assistance of black cover glass surface, the glass is protecting the cell from the elements of atmosphere. The reflection losses of the photons are reduced to less than 5% by the anti-reflective coating. The travelling distance of the Photons The photovoltaic cells structure is quite straightforward. It consists of 6 different was minimized by contact grid, so that it able to reach the semiconductors.

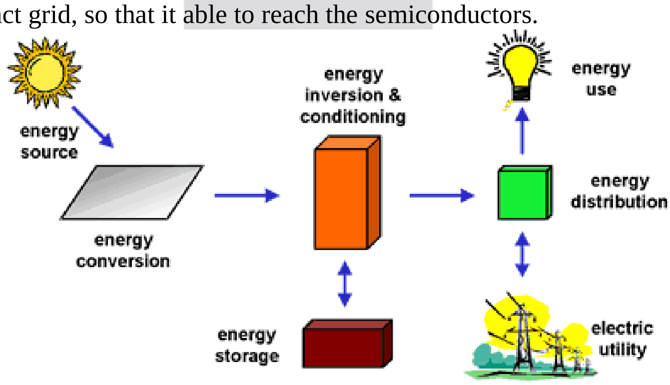

Fig.2 Photovoltaic Structure

III. Photovoltaic Effect

The sun light beam is the main key to create the photovoltaic effect. Electrons will be stimulated when the photons in the photovoltaic cell exposed to the sun light beam. The electrons will jump into the conduction band after it starts moving rapidly, and then holes in the valence band leaved by electrons. Holes of nearby p-side are combining with electrons attracted from opposite direction which is n-side.

The electric current in the photovoltaic cell is creating by electrons from one of semiconductor flow over to the other. In addition, if grooved Si surface and the coating of anti-reflective surface can be used, it can definitely maximize the absorption of the photons in the Photovoltaic cell. Besides that, the open circuit voltage will occur if the current is indicated minimum (zero) value, the resistance in the circuit is infinite and the voltage reaches maximum value. Otherwise, the short circuit will happen if the current of circuit reaches the maximum value, the resistance of circuit is zero.

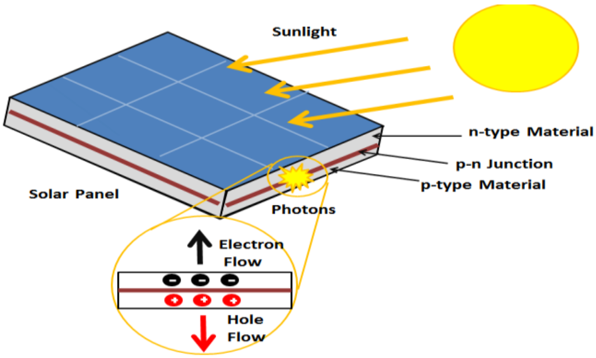

Fig.3. Photovoltaic Effect

IV. Main Cell Types

The material that is used widely in the industry for the production of photovoltaic cells is silicon. Silicon can be found inside the sand in the form of silicon oxide ($SiO2$). The final product is characterized by high purity 99.99999%. The photovoltaic cells of silicon are distinguished in four categories, depending on the structure of the basic material from which they are made and the particular way of their preparation. The types are the following ones:

Single-Crystal Silicon: The basic material is monocrystalline silicon. In order to make them, silicon is purified, melted, and crystallized into ingots. The ingots are sliced into thin wafers (Wafer~300μm) to make individual cells. The efficiency of a single crystal silicon cell oscillates between 13-16% and it is characterized by a high cost for the manufacture and has a dark blue colour. Polycrystalline Silicon: The particular cell is relatively large in size and it can be easily formed into a square shape which virtually eliminates any inactive area between cells. Its efficiency oscillates between 10-14% and it is characterized by lower cost silicon which is used for its manufacture and has light blue colour. Ribbon Silicon: Ribbon-type photovoltaic cells are made by producing a ribbon from the molten crystal silicon instead of an ingot. Its efficiency is around 13% and is very expensive with a limited industrial production.

V. Main Parts of a Photovoltaic System

Photovoltaic system is consisting of various devices. The complete photovoltaic system is constituted by inverter, charge controller and batteries. In this renewable energy system, the energy produced by Photovoltaic cell is
Stored in the batteries. Furthermore, Energy will be supplied to the system, it generally happens at nights, cloudy days and days which are required higher electrical demands. Deep-cycle batteries is the most common type of batteries and commonly be used. Deep-cycle batteries are categorised as type of lead-acid battery and advantages of wide range of usage. Nickel-cadmium battery is very costly, but the energy stored can be discharged at the higher level than lead-acid battery and high level of durability.

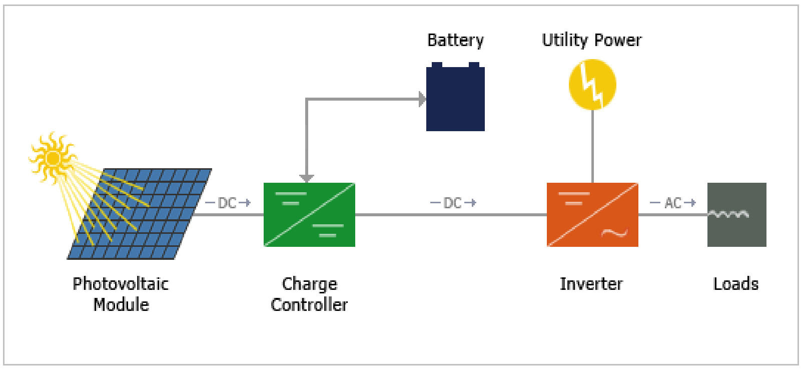

Fig.4. Parts of PV System

Deep-cycle batteries is the most common type of batteries and commonly be used. Deep-cycle batteries are categorised as type of lead-acid battery and advantages of wide range of usage. Nickel-cadmium battery is very costly, but the energy stored can be discharged at the higher level than lead-acid battery and high level of durability. (Before the photovoltaic system connects to the grid, it is required to consider the characteristics of the batteries as follows:

a) Battery total capacity is representing the total load of battery (Ampere hour) that the energy capable to be stored in the battery.

b) Battery voltage is defined according to the electrolyte type and the elements number.
c) Discharge depth represents that the battery discharge level which is capable to achieve in daily.
d) The cost per kWh represents that the total electrical energy to be calculated while the batteries supplying the power during the life cycle.
e) The battery operational life shows that the battery life cycle in the photovoltaic's system, the battery has to be replaced after 5-6 years operation.
f) Charge controller is an important device for the battery life cycle. In the operation mode of charge controller, the life of battery will be reduced if overcharge occurs in the battery. In order to increase the battery life, the charge controller will block the electrical load continuously flowing in while the batteries are fully charged.
g) The inverter is an important device that able to convert alternative current (AC) from direct current (DC Alternative current usage is essential and crucial, since it has been widely used for all variety of industry sector and domestic uses. It is used, generally, in cases where a source of continuous electric voltage is allocated and where an alternative electric voltage is used, as it happens with
h) The installed PV cells on the buildings. The efficiency of the inverter is quite high and varies between 93% and 96%.

MAIN PRINCIPLES OF PV SYSTEMS

A photovoltaic cell is rarely used in single set or individually, since it is unable to supply sufficient power and voltage of electronic device requirement. Due to this reason, it needs more set of photovoltaic cells be coupled together and to be connected parallel or in series for energy production, in order to achieve the higher power output and voltage as possible.

A typical photovoltaic system is made of 36 individual 100 cm² silicon photovoltaic cells and auxiliary devices which are lead-acid batteries with a typical voltage of 12 V. This system has the capacity of producing more than 13V during cloudy days and can charge a 12 V battery.

In order to utilise the system efficiently, it is required to understand that how does it works during various electrical loads connected in the system.

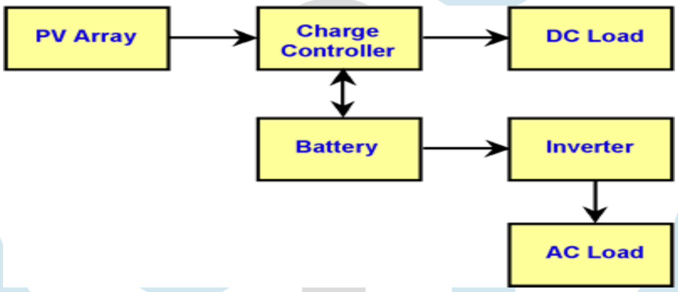

Fig.5. Principle of PV System

In real conditions, the function of a photovoltaic system may be varied because of the intensity fluctuation of the solar radiation over a period of time. When the light of photovoltaic cells, which supplies an electrical resistance, changes, the power point shifts. This point can be seen experimentally, if the electric power, which is provided by the PV cell with a given power density E and applied on a variable electric resistance. Since the resistance varies, fluctuations can be measured in current and voltage by using the appropriate measurement devices; ammeter and voltmeter. In Figure 2.5, it can be observed that presents a peak point in the "knee" of the I-V curve. The values of the electrical current in the maximum power point are symbolized with I_m and V_m . The max power, which a PV cell can produce, is calculated as follows:

$$P_{max} = V_{max} \times I_{max}$$

Using the max power and the appropriate I-V curve, the fill factor can be calculated. Fill factor is the key characteristic in evaluating cell performance of

PV cell, while it can also show that the efficiency of photovoltaic system. As the values of the fill factor are closer to the unit 1, the efficiency of the system performance will be increased. Typical values of the fill factor for a PV cell which has a quite high efficiency are between 0.7 and 0.9.

$$FF = \frac{V_{max} \times I_{max}}{I_{sc} \times V_{oc}}$$

In order to calculate the electrical power generated from a photovoltaic panel, P_{out}, the total solar irradiance, T_{otal}, and the efficiency of the electrical conversion, εE, have to be calculated. The solar radiation which reaches the earth has two different components; the beam radiation and the diffuse radiation. So by adding these two values, the total solar irradiance for a point on the surface of the earth, can be calculated

$$G_{total} = G_{beam} + G_{diffuse}$$

The electrical conversion can be calculated using the following formula.

$$\varepsilon_E = E_{stc} \times (1 - P_p \times (T_{module} - T_{reference}))$$

A is the floor area of the panel

$$P_p = \frac{power\ drop\ off}{P_{max}}$$

So as to calculate the electricity generated from a PV component, the following equation is used

$$P_{out} = G_{total} \times A \times \varepsilon_E$$

Also the power entering the system can be calculated using the formula below:

$$P_{in} = \tau\alpha \times A \times G_{total}$$

And the system's power loss from the component can be calculated using the following formula:

$$P_{loss} = U \times A \times (T_{module} - T_{air})$$

Where U is the overall heat transfer coefficient (W/m2*K)

Using all the above values, the useful power supply from a PV cell can be derived from the equation below:

$$Q_h = P_{in} - P_{out} - P_{loss}$$

Finally, the effectiveness of the electrical power output from a PV cell and the efficiency of a PV system can be calculated as follows:

$$\frac{P_{out}}{P_{max}} \times 100\ (Effectiveness)$$

$$\frac{(P_{out}+Q_h)}{P_{in}} - 100\ (Effeciency)$$

WIND ENERGY SYSTEM

I. General

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. Click on the image to see an animation of wind at work. So how do wind turbines make electricity? Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. View the wind turbine animation to see how a wind turbine works or take a look inside. Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth. Wind flow patterns and speeds vary greatly across the United States and are modified by bodies of water, vegetation, and differences in terrain. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity. The terms wind energy or wind powers describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power.

II. Basic Operartion of Wind System

a) Wind (moving air that contains kinetic energy) blows toward the turbine's rotor blades.
b) The rotors spin around, capturing some of the kinetic energy from the wind, and turning the central drive shaft that supports them. Although the outer edges of the rotor blades move very fast, the central axle (drive shaft) they're connected to turns quite slowly.
c) In most large modern turbines, the rotor blades can swivel on the hub at the front so they meet the wind at the best angle (or "pitch") for harvesting energy. This is called the pitch control mechanism. On big turbines, small electric motors or hydraulic rams swivel the blades back and forth under precise electronic control. On smaller turbines, the pitch control is often completely mechanical. However, many turbines have fixed rotors and no pitch control at all.
d) Inside the nacelle (the main body of the turbine sitting on top of the tower and behind the blades), the gearbox converts the low-speed rotation of the drive shaft (perhaps, 16 revolutions per minute, rpm) into high-speed (perhaps, 1600 rpm) rotation fast enough to drive the generator efficiently.
e) The generator, immediately behind the gearbox, takes kinetic energy from the spinning drive shaft and turns it into electrical energy. Running at maximum capacity, a typical 2MW turbine generator will produce 2 million watts of power at about 700 volts.

f) Anemometers (automatic speed measuring devices) and wind vanes on the back of the nacelle provide measurements of the wind speed and direction.
g) Sing these measurements, the entire top part of the turbine (the rotors and nacelle) can be rotated by a yaw motor, mounted between the nacelle and the tower, so it faces directly into the oncoming wind and captures the maximum amount of energy. If it's too windy or turbulent, brakes are applied to stop the rotors from turning (for safety reasons). The brakes are also applied during routine maintenance.
h) The electric current produced by the generator flows through a cable running down through the inside of the turbine tower.
i) A step-up transformer converts the electricity to about 50 times higher voltage so it can be transmitted efficiently to the power grid (or to nearby buildings or communities). If the electricity is flowing to the grid, it's converted to an even higher voltage (130,000 volts or more) by a substation nearby, which services many turbines.
j) Homes enjoy clean, green energy: the turbine has produced no greenhouse gas emissions or pollution as it operates.
k) Wind carries on blowing past the turbine, but with less speed and energy (for reasons explained below) and more turbulence (since the turbine has disrupted its flow).

All of the components (blades, shaft, and generator) are on top of a tall tower, and the blades face into the wind. The shaft is horizontal to the ground. The wind hits the blades of the turbine that are connected to a shaft causing rotation. The shaft has a gear on the end which turns a generator. The generator produces electricity and sends the electricity into the power grid. The wind turbine also has some key elements that add to efficiency. Inside the Nacelle (or head) are an anemometer, wind vane, and controller that read the speed and direction of the wind. As the wind changes direction, a motor (yaw motor) turns the nacelle so the blades are always facing the wind. The power source also comes with a safety feature. In case of extreme winds the turbine has a break that can slow the shaft speed. This is to inhibit any damage to the turbine in extreme conditions. Wind turbines are used to generate electricity from the kinetic power of the wind. Historical they were more frequently used as a mechanical device to turn machinery. There are two main kinds of wind generators, those with a vertical axis, and those with a horizontal axis. Wind turbines can be used to generate large amounts of electricity in wind farms both onshore and offshore.

TYPES OF WIND TURBINE
Wind turbine is classified into two types is given below
1. Horizontal axis wind turbine
2. Veritical axis wind turbine

I. Horizontal axis wind turbine

Large three-bladed horizontal-axis wind turbines (HAWT), with the blades upwind of the tower produce the overwhelming majority of wind power in the world today. These turbines have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a yaw system. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Fig.6. Horizontal Axis Turbine

II. Veritial axis wind turbine

In vertical axis turbines the shaft the blades are connected to is vertical to the ground. All of the main components are close to the ground. Also, the wind turbine itself is near the ground, unlike horizontal where everything is on a tower. There are two types of vertical axis wind turbines; lift based and drag based. Lift based designs are generally much more efficient than drag, or 'paddle' designs

Fig.7. Vertical Axis Wind Turbine

III. Sizes of Wind Turbines

Utility-scale turbines range in size from 100 kilowatts to as large as several megawatts. Larger wind turbines are more cost effective and are grouped together into wind farms, which provide bulk power to the electrical grid. Offshore wind turbines are larger, can generate more power, and do not have the same transportation challenges of land-based wind installations, as the large components can be transported on ships instead of on roads. The shaft has a gear on the end which turns a generator. The generator produces electricity and sends the electricity into the power grid. The wind turbine also has some key elements that add to efficiency. Inside the Nacelle (or head) are an anemometer, wind vane, and controller that read the speed and direction of the wind. As the wind changes direction, a motor (yaw motor) turns the nacelle so the blades are always facing the wind. All of the components (blades, shaft, and generator) are on top of a tall tower, and the blades face into the wind. The shaft is horizontal to the ground. The wind hits the blades of the turbine that are connected to a shaft causing rotation. The shaft has a gear on the end which turns a generator. The generator produces electricity and sends the electricity into the power grid. The wind turbine also has some key elements that add to efficiency. Inside the Nacelle (or head) are an anemometer, wind vane, and controller that read the speed and direction of the wind. As the wind changes direction, a motor (yaw motor) turns the nacelle so the blades are always facing the wind.

POWER FLOW ANALYSIS METHOD

I. General

The power-flow study, or load-flow study, is a numerical analysis of the flow of electric power in an interconnected system. A power-flow study usually uses simplified notations such as a one-line diagram and per-unit system, and focuses on various aspects of AC power parameters, such as voltages, voltage angles, real power and reactive power. It analyzes the power systems in normal steady-state operation. Power-flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power-flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line. Commercial power systems are usually too complex to allow for hand solution of the power flow. Special purpose network analyzers were built between 1929 and the early 1960s to provide laboratory-scale physical models of power systems. Large-scale digital computers replaced the analog methods with numerical solutions. In addition to a power-flow study, computer programs perform related calculations such as short-circuit fault analysis, stability studies (transient and steady-state), unit commitment and economic dispatch.[1] In particular, some programs use linear programming to find the optimal power flow, the conditions which give the lowest cost per kilowatt hour delivered.

A load flow study is especially valuable for a system with multiple load centres, such as a refinery complex. The power flow study is an analysis of the systems. Capability to adequately supply the connected load. The total system losses, as well as individual line losses, also are tabulated. Transformer tap positions are selected to ensure the correct voltage at critical locations such as motor control centres. Performing a load flow study on an existing system provides insight and recommendations as to the system operation and optimization of control settings to obtain maximum capacity while minimizing the operating costs. The results of such an analysis are in terms of active power, reactive power, magnitude and phase angle. Furthermore, power-flow computations are crucial for optimal operations of groups of generating units.

II. Classification of Buses

There are four quantities associated with each bus. They are PI, QI, IVI, and δ. Here

`PI' is the real power injected into the bus
`QI' is the reactive power injected into the bus
`IVI' is the magnitude of the bus voltage
`δ' is the phase angle of the bus voltage

Any two of these four may be treated as independent variables (i.e. specified) while the other two may be computed by solving the power flow equations. Depending on which of the two variables are specified, buses are Classified into three types. Three types of bus classification based on practical requirements are shown below.

1. Slack bus
2. Generator bus
3. Load bus

Slack bus

In a power system with N buses, power flow problem is primarily concerned with determining the 2N bus voltage variables, namely the voltage magnitude and phase angles. These can be obtained by solving the 2N power flow equations provided there are 2N power specifications. However as discussed earlier the real and reactive power injection at the SLACK BUS cannot be specified beforehand. This leaves us with no other alternative but to specify two variables sV and sδ arbitrarily for the slack bus so that 2(N-1) variables can be solved from 2(N-1) known power specifications. Incidentally, the specification of sV helps us to fix the voltage level of the system and the specification of sδ serves as the phase angle reference for the system. Thus for the slack bus, both V and δ are specified and PI and QI are to be determined. PI and QI can be computed at the end, when all the Vs and δ s are solved for.

Generator bus

In a generator bus, it is customary to maintain the bus voltage magnitude at a desired level which can be achieved in practice by proper reactive power injection. Such buses are termed as the Voltage Controlled Buses or P – V buses. In these buses, PI and V are specified and QI and δ are to be solved for.

Load bus

The buses where there is no controllable generation are called as Load Buses or P – Q buses. At the load buses, both PI and QI are specified and V and δ are to be solved. The power flow equations are non-linear, thus cannot be solved analytically. A numerical iterative algorithm is required to solve such equations. A standard procedure follows:

1. Create a bus admittance matrix Y bus for the power system;
2. Make an initial estimate for the voltages (both magnitude and phase angle) at each bus in the system;
3. Substitute in the power flow equations and determine the deviations from the solution.
4. Update the estimated voltages based on some commonly known numerical algorithms (e.g., Newton-Raphson or Gauss-Seidel).
5. Repeat the above process until the deviations from the solution are minimal.

III. Types of Power Flow Analysis Method

The power flow analysis types are given below:

1. Gauss seidal method
2. Newton rapshon method
3. Fast decoupled method

In this project we can used the Newton rapshon method are described as given below

$$\mathbf{I_i = Y_{i1}\,V_1 + Y_{i2}\,V_2 + \cdots\cdots + Y_{iN}\,V_n}$$
$$\mathbf{= \sum_{n=1}^{N} Y_{in}\,V_n}$$

NEWTON RAPSHON METHOD

I. Introduction to Power Flow Analysis by Newton Raphson method:

Gauss-Seidel method of solving the power flow has simple problem formulation and hence easy to explain However, it has poor convergence characteristics. It takes large number of iterations to converge. Even for the five bus system discussed , it takes 10 iterations to converge. Newton Raphson (N.R.) method of solving power flow is based on the Newton Raphson method of solving a set of non-linear algebraic equations. N. R. method of solving power flow problem has very good convergence characteristics. Even for large systems it takes only two to four iterations to converge.

II.Power Flow Model of Newton Raphson Method:

The equations describing the performance of the network in the bus admittance form is given by I = Y V

In expanded form these equations are

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_N \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1N} \\ Y_{21} & Y_{22} & \cdots & Y_{2N} \\ \vdots & \vdots & & \vdots \\ Y_{N1} & Y_{N2} & \cdots & Y_{NN} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_N \end{bmatrix}$$

Typical element of the bus admittance matrix Is

$$Y_{ij} = |Y_{ij}| \angle\theta_{ij} = |Y_{ij}| \cos\theta_{ij} + j\,|Y_{ij}| \sin\theta_{ij} = G_{ij} + j\,B_{ij}$$

Voltage at a typical bus i is

$$V_i = |V_i| \angle\delta_i = |V_i| (\cos\delta_i + j\sin\delta_i)$$

The current injected into the network at bus i is given byIn addition to the linear network equations given, bus power equations should also be satisfied in the flow problem.

$$P_i = \sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i)$$

$$Q_i = -\sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i)$$

The real and reactive powers obtained from the above two equations are referred as calculated powers. During the power flow calculations, their values depend on the latest bus voltages. Finally, these calculated powers should be equal to the specified powers. Thus the non-linear equations to be solved in power flow analysis are

$$\sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i) = PI_i$$

$$-\sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i) = QI_i$$

It is to be noted that equation (2.46) can be written for bus i only if real power injection at bus i is specified. Similarly, equation (2.47) can be written for bus i only if reactive power injection at bus i is specified.

$$\sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i) = PI_i$$

$$-\sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i) = QI_i$$

The N total number of buses in the power system, let the number of P-Q buses be N_1, P-V buses be N_2. Then $N=N_1+N_2+1$. Basic problem is to find the Unknown phase angles δ at the N_1+N_2 ,number of P-V and P-Q buses Unknown voltage magnitudes |V| at the N_1 number of P-Q buses Thus total number of unknown variables $=2N_1+N_2$.

We can write N_1+N_2 real power specification equations (eqn.2.46) and N_1 reactive power specification equations (eqn.2.47). Thus total number of equations $=2N_1+N_2$. Therefore Number of equations = Number of variables $=2N_1+N_2$.

$$\sum_{n=1}^{N} |V_i|\,|V_n|\,|Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i) = PI_i$$

$$\text{for } i = 1, 2, \ldots\ldots, N$$

$$i \neq s$$

Thus in power flow study, we need to solve the equations

$$- \sum_{n=1}^{N} |V_i| |V_n| |Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i) = QI_i$$

For i = 1, 2… N
i ≠ s
i ≠ P – V buses
For the unknown variables δi i = 1, 2... N, i ≠ s and
|Vi| i = 1, 2… N, i ≠ s, i ≠ P – V buses

III.Algorithm for Newton Raphson Method:

Step 1: Form Y bus.
Step 2: Assume the initial value of the bus voltages $|Vi|^0$ and phase angle δi^0 for i = 2, 3…N for load buses and phase angles for PV buses. Normally we set the assumed bus voltage magnitude and its phase angle equal to the slack bus quantities $|V_1| = 1.0$, $\delta_1 = 0^0$.
Step 3: Compute P_i and Q_i for each load bus from the following equation (5) and (6) shown above.
Step 4: Now, compute the scheduled errors ΔPi and ΔQi for each load bus from the following relations given below
Step 5: For PV buses, the exact value of Qi is not specified, but its limits are known. If the calculated value of Qi is within the limits only ΔPi is calculated. If the calculated value of Qi is beyond the limits, then an appropriate limit is imposed and ΔQi is also calculated by subtracting the calculated value of Qi from the appropriate limit. The bus under consideration is now treated as a load bus.
Step 6: Compute the elements of the Jacobian matrix.

$$\begin{bmatrix} H & N' \\ M & L' \end{bmatrix}$$

Step 7: Obtain the value of Δδ and Δ|Vi| from the equation shown below.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N' \\ M & L' \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{\Delta V}{V} \end{bmatrix}$$

Step 8: Using the values of Δδi and Δ|Vi| calculated in the above step, modify the voltage magnitude and phase angle at all load buses by the equations shown below.

$$\left|V_i^{(r+1)}\right| = \left|V_i^{(r)}\right| + \Delta \left|V_i^{(r)}\right|$$

$$\delta_i^{(r+1)} = \delta_i^{(r)} + \Delta\delta_i^{(r)}$$

Step 9: Start the next iteration cycle following the step 2 with the modified values of |Vi|and δi.

Step 10: Continue until scheduled errors for all the load buses are within a specified tolerance that is

$$\Delta P_i^{(r)} < \varepsilon, \qquad \Delta Q_i^{(r)} < \varepsilon$$

Where, ε denotes the tolerance level for load buses.

Step 11: Calculate the line and power flow at the slack bus same as in the Gauss Seidel method.

IV. **Flow Chart of Newton Rapshon Method:**

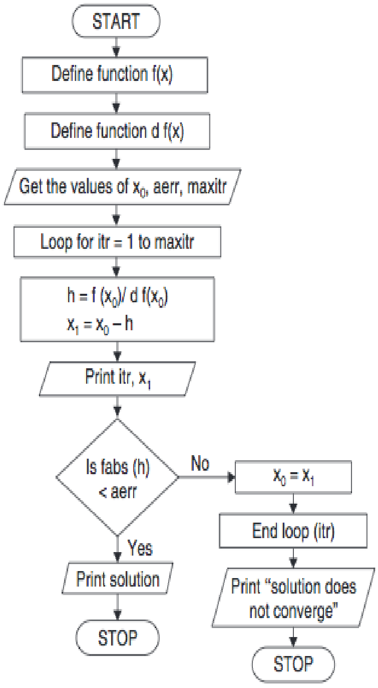

Fig. 1. Flow Chart of Newton Raphson

OPTIMAL DG LOCATION

I. Whale Optimization Method

Recently a new optimization algorithm called whale optimization Algorithm (Mirjalili 2016) has been introduced to metaheuristic algorithm by Mirjalili and Lewis. The whales are considered to be as highly intelligent animals with motion. The WOA is inspired by the unique hunting behaviour of humpback whales. Usually the hump back whales prefer to hunt krill's or small fishes which areclose to the surface of sea. Humpback whales use a special unique hunting method called bubble net feed in method. In this method they swim around the prey and create distinctive bubbles along a circle or 9-shapedpath.

The mathematical model of WOA is described in the following sections

1. Encircling prey.
2. Bubble net hunting method.
3. Search the prey

II. Inspiration and foraging behavior:

Whales are considered as the biggest mammals in the world. They are intelligent due to the spindle cells in their brain. The whales are living in groups and they are able to develop their own dialect. There are 7 types of whales and the humpback whale is one of these types.

Fig. 8. Inspiration Behavior

Fig. 9. Foraging Behavior

It has a special hunting mechanism which is called bubble-net feeding method. This foraging behavior is done by crating special bubbles in a spiral shape or (9 shape) path.

III. Encircling prey:

Humpback whales know the location of prey and encircle them. They consider the current best candidate solution is best obtained solution and near the optimal solution. After assigning the best candidate solution, the other agents try to update their positions towards the best search agent as shown in the following equation

Fig 10. Encircling Prey

$$D=|C.X^*(t)-X(t)|$$

$$X(t+1)=X^*(t)-A.D$$

Where ***t*** is the current iteration, **a** and **c** are coefficient vectors, **x*** is the position vector of the best solution, and **x** indicates the position vector of a solution,| | is the absolute value.

Fig 11. Encircling Prey

$$A=2a.r.a$$
$$C=2.r$$

Where components of a are linearly decreased from 2 to 0 over the course of iterations and r is random vector in [0; 1].

IV.Shrinking Encircling Mechanism:

In this mechanism, the value of **A** is a random value in interval [-a, a] and the value of **a** is decreased from 2 to 0 over the course of iterations.

Fig 12. Shrinking Encircling Mechanism

In this mechanism, the distance between the whale location and the prey location is calculated then the helix-shaped movement of humpback is created as shown in the following equation.

$$X(t+1)=D^l.e^{bl}.\cos(2\pi L)+X^*(t)$$

Where **D' =| X*(t) - X(t) |** is the distance between the prey (best solution) and the i^{th} whale, b is a constant, l is a random number in [-1; 1]. We set the mathematical model of these two mechanisms, we assume that there is a probability of 50% to chose between these two mechanisms to update the position of whales as follow

EXPLORATION PHASE

Search for prey in the exploration phase, the humpback whales (search agents) search for prey (best solution) randomly and change their positions according the position of other whales. In order to force the search agent to move far away from reference whale, we use the A with values > 1 or >1 the mathematical model of the exploration phase is as follows.

I. Whale Optimization Algorithm

Step 1:
Solve the feeder-line flow for the system.

Step 2:
Calculate the IV of bus n

Step 3:
Index vector was arranged in descending order.

Step 4:
Normalized voltage values by V (i) = V (i)/0.95.

Step 5:
Buses with <1.01 is suitable locations for DG Sizing.

II. Whale Optimization Flowchart

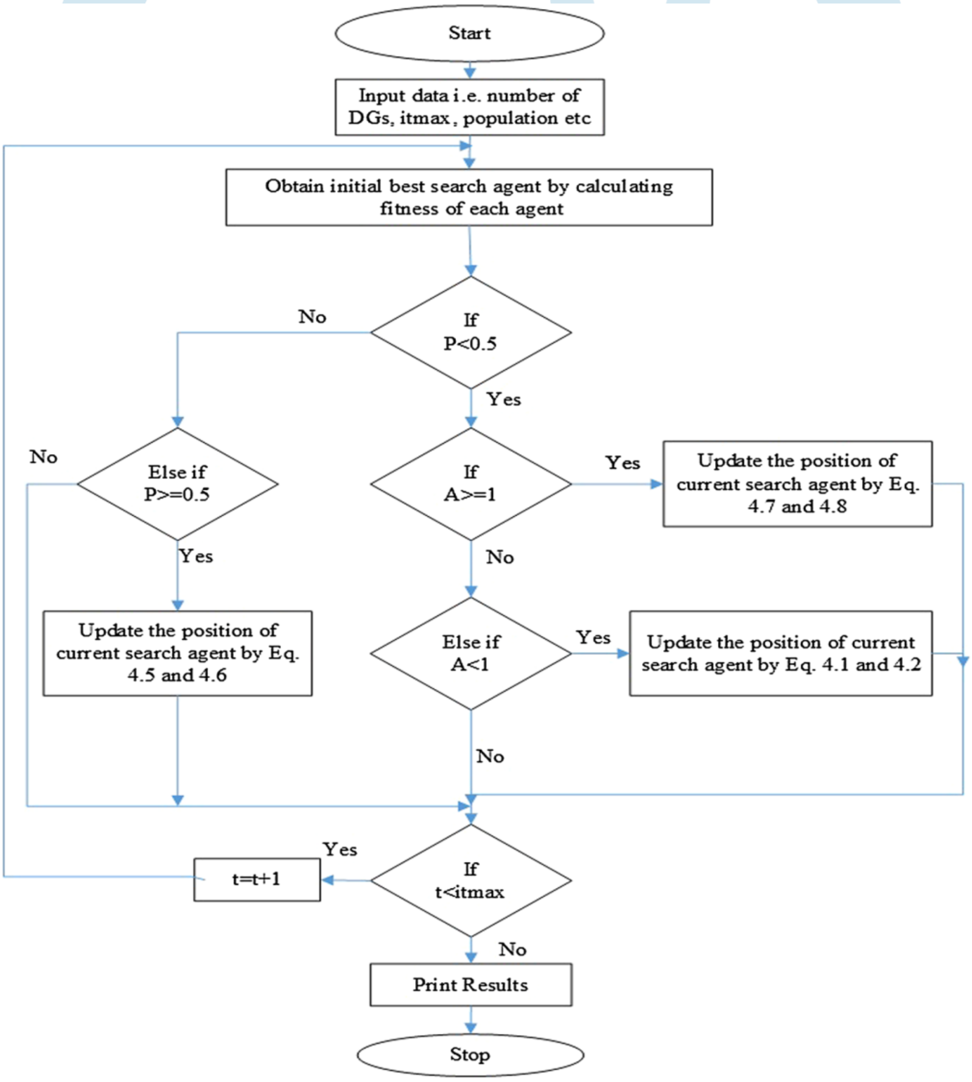

Fig.2. Flow Chart of Whale Optimization

RESULT AND DISCUSSION

I. Radial 33 Bus System

We are considering 33 buses single line diagram of radial distribution system is given below.

Single line diagram

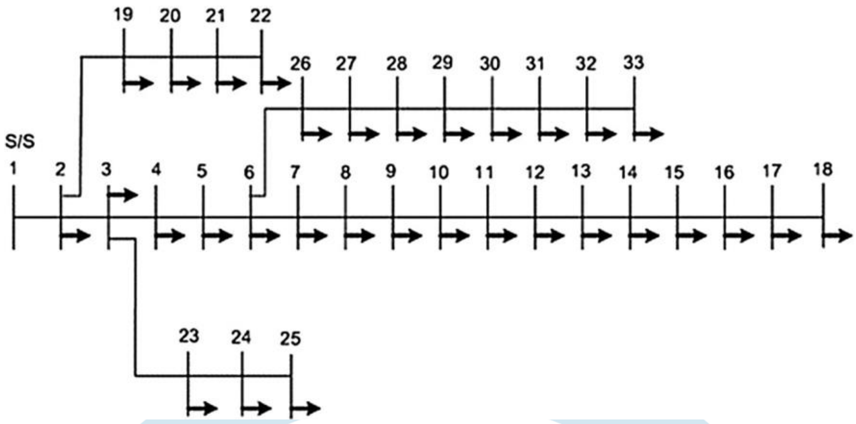

Fig.13. Single Line diagram.

II. POWER FLOW RESULT

The power flow result is obtained by using Newton rapshon method. The power flow result in given below.

Table.1. 33 Bus Radial Distribution Load Flow Output

Bus No	Voltage Pu	Stability index Pu	Del angle	Pd Kw	Qd KVar
1	1.0000	1.0000	0.0000	0.000	0.000
2	0.9970	0.9994	0.0013	100.000	60.000
3	0.9828	0.9846	0.0055	90.000	40.000
4	0.9753	0.9314	0.0046	120.000	80.000
5	0.9679	0.9033	0.0063	60.000	30.000
6	0.9493	0.8739	0.0312	60.000	20.000
7	0.9458	0.8119	0.1918	200.000	100.000
8	0.9322	0.7987	0.3460	200.000	100.000
9	0.9258	0.7545	0.4211	60.000	20.000
10	0.9199	0.7343	0.4862	60.000	20.000
11	0.9191	0.7161	0.4797	45.000	30.000
12	0.9175	0.7134	0.4696	60.000	35.000
13	0.9113	0.7085	0.5628	60.000	35.000
14	0.9091	0.6899	0.6411	120.000	80.000
15	0.9077	0.6830	0.6788	60.000	10.000
16	0.9063	0.6787	0.7026	60.000	20.000
17	0.9042	0.6746	0.7794	60.000	20.000
18	0.9036	0.6686	0.7893	90.000	40.000
19	0.9965	0.9383	0.1222	90.000	40.000
20	0.9929	0.9859	0.0789	90.000	40.000
21	0.9922	0.9718	0.0993	90.000	40.000
22	0.9915	0.9691	0.1199	90.000	40.000
23	0.9792	0.9149	0.0367	90.000	50.000
24	0.9725	0.9191	0.1259	420.000	200.000
25	0.9692	0.8944	0.1699	420.000	200.000
26	0.9474	0.8175	0.0692	60.000	25.000
27	0.9449	0.8055	0.1231	60.000	20.000
28	0.9334	0.7959	0.2061	60.000	20.000
29	0.9251	0.7585	0.2834	120.000	70.000
30	0.9216	0.7325	0.3851	200.000	600.000
31	0.9174	0.7211	0.3057	150.000	70.000
32	0.9164	0.7082	0.2840	210.000	100.000
33	0.9613	0.7054	0.2767	60.000	40.000

III. OBTAIN THE OPTIMAL LOCATION

The optimal location will be obtained by using the whale optimization algorithm. The whale optimization algorithm results in given below.

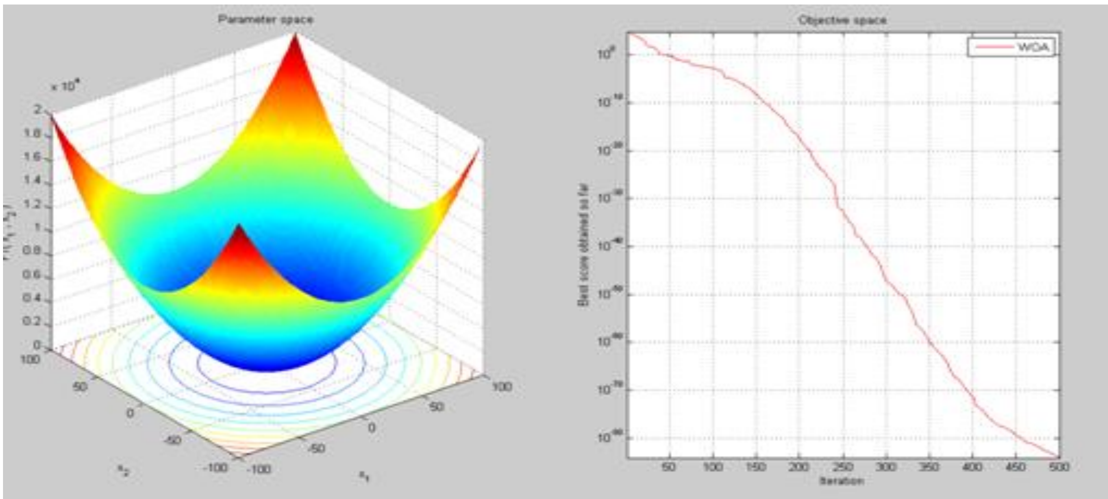

Fig 14. Whale Optimization Result Output

IV. Optimal Location Result:

The single line diagram of IEEE 33 bus distribution system as shown in fig.6.1.1.the system voltage is 12.62kv and total system active and reactive loads are 3715 kW and 2295 KVar, respectively. This test is consist a 33 buses and 32 branches.

Table 2. 33 Bus Radial Bus System Result.

Description	Without DG	With type DG
DG location	-	19
DG size	-	3015.527
TLP(pu)	0.5027	0.134
TLG(pu)	0.8322	0.447
V_{Min}	0.9036	0.9645

Here ,output bus voltage Comparison of with DG location and without DG location.

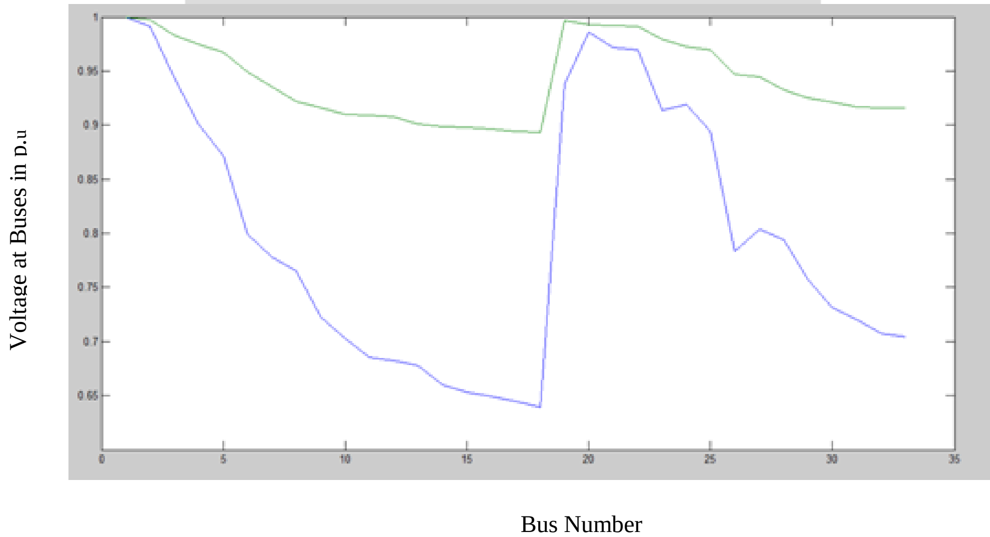

Fig 15. Comparison of with DG location and without DG location.

CONCLUSION

A novel nature-inspired whale optimization algorithm is used to determine the optimal DG size in this paper. WOA is modelled based on the unique hunting improvement behaviour of humpback whales. Reduction of system power losses and in voltage profile is the objectives taken in this paper. The proposed method has been applied on typical IEEE 33 bus radial distribution systems with different types of DGs and compared with other algorithms. Better results have been achieved with WOA when compared with other algorithms. The simulation results indicated that the overall impact of the DG units on voltage profile is positive and proportionate reduction in power losses is achieved. It can be interfered that best results can be achieved with type III DG operating at 0.9 pf, because it generates both real power and reactive power. The results show that the WOA is efficient and robust.

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