PLANNING OF A MICROGRID

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

POWER ELECTRONICS AND DRIVES

BY

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled "**Planning of a microgrid**" in partial fulfilment of the requirements for the award of **Master of Technology** degree in **Electrical Engineering** submitted in Electrical Engineering department of National Institute of Technology, Rourkela is an authentic record of my own work carried out under the supervision of Dr.SanjibGanguly, Assistant professor, Department of Electrical Engineering.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

(**Guguloth Nehru**)

This is to certify that the above statement made by candidate is correct and true to best of my knowledge.

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ABSTRACT

Microgrid planning is very important for generation and transmission expansion planning in electrical power system. This is an option for co-streamlining of era and transmission extension arranging.In distribution system, all connected microgrids transfer energy from its central to local sources for the network reliability satisfaction and also it satisfies the power quality required by local loads. The main objective is to minimize the power losses in the transmission planning by using distributed generators in 30 bus system and 52 bus system. Newton Raphson method is applied for load flow analysis to get the voltage and load angle for each bus in 30 bus system and 52 bus system. An optimization technique is used for getting optimal values in this transmission planning. Differential evolution algorithm technique is used as optimization technique in this planning. This optimization technique is applied to 30 bus system and 52 bus system. Simulation results demonstrate the effectiveness of distributed generators in microgrid planning.

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1. CHAPTER

Introduction:

Microgrids are little scale, low voltage combined heat and power supply system intended to supply electrical furthermore, warmth loads for a little group, for example, a lodging home or a rural territory, or open group, for example, a college or school, a business territory, a mechanical site, an exchanging home or a civil locale. Microgrid is basically a distributed system on the ground that it is the combination of distributed generation frameworks and diverse burdens at circulation voltage levels. The generators or micro sources utilized in a microgrid are typically renewable or non-routine distributed energy resources incorporated together to produce power at conveyance voltage. From operational perspective, the micro sources must be outfitted with force electronic interfaces and controls to give the obliged adaptability to guarantee operation as a solitary amassed framework and to keep up the predefined forced quality and vitality yield. This control adaptability would permit the microgrid to present itself to the primary utility force framework as a solitary controlled unit that meets neighbourhood vitality requirements for unwavering quality and security.

The key contrast between a microgrid and traditional force plant are as take after:

(1) Micro sources are of much littler limit regarding the expansive generators in routine force plants.
(2) Power produced at conveyance voltage can be straight forwardly encouraged to the utility of appropriation system.
(3) Micro sources are ordinarily introduced near to the clients premises so that the electrical burdens can be productively supplied with palatable voltage what's more, recurrence profile and irrelevant line misfortunes.

The specialized highlights of a microgrid make it suitable for supplying energy to remote regions of a nation where supply from the national network framework is either hard to benefit because of the topology oftentimes upset because of serious climatic conditions or manmade aggravations. From matrix perspective, the principle favourable position of a microgrid is that it is dealt with as a controlled element inside of the force framework. It can be worked as a solitary

accumulated load. This finds its simple controllability and consistence with matrix principles and regulations without hampering the unwavering quality and security of the force utility. From clients prospective, microgrids are advantageous for generally meeting their electrical or heat prerequisites. They can supply uninterruptible force, enhance neighbourhood dependability, lessen feeder misfortunes and give nearby voltage support. From ecological perspective, microgrids lessen natural contamination and a worldwide temperature alteration through usage of low carbon innovation.

Then again, to accomplish a steady and secure operation, various specialized, administrative and financial issues must be determined before microgrids can get to be typical. Some issue zones that would require due considerations are irregular also, atmosphere subordinate nature of era of the distributed energy resources, low vitality content of the powers and absence of benchmarks and regulations for working with microgrids in synchronism with the force utility. The investigation of such issues would require far reaching constant and disconnected from net examinations, which can be taken up by the main building and examination foundation over the globe.

Microgridsproduce, convey and manage the electricity stream to the neighbourhood clients. Microgrid represents as a little scale power framework due to its high level of adaptability and proficiencyin the area of supply and interest part [1]-[5]. We can technically define, microgrid is a system with at least one demand that could be islanded from the main distribution power system and having at least one distributed energy resources. Practically, microgrids are to be introduced to address the emergency of huge numbers of distributed energy resources in distribution power system and to guarantee secure and ideal operations of possibly islanded force network.

Microgrid is treated as controllable load from the utility perspective. The distributed energy resources are located within the microgrid which is differ from power plant because they have littler limit and they are straightforwardly joined with the microgrid appropriation system and this can be redone to supply nearby load prerequisites [6].

The main advantages of microgrid is improves the unwavering qualityalong with introduction of self recuperating at the nearby dispersion system, gives higher force quality by

maintaining the neighbourhood loads, decrease in the emanation of carbon by the expansion of vitality sources, financial operation by reducing the transmission and distribution costs, utilizing less cost renewable energy sources and giving energy efficiency [7]-[10].

The main aspect of microgrid is capacity to be islanded from the main lattice by upstream switches at the purpose of regular coupling. For the purpose of economic and reliability this islanding is introduced. Islanding means, if any disturbances occur from the main power grid, microgrid is exchanged from the lattice associated with the islanded mode and a dependable and continuous supply of customer burdens is offered by neighbourhood era assets. Once the disturbance is removed in main power grid, we can resynchronize the islanded microgrid to the main power grid [11]-[13]. Microgrid reduces the total system planning cost and due to its ability it increases the system reliability, so that it lowers the possibility of load shedding. Microgridsoffer a lower development time also, are viewed as suitable choices for lessening the transmission clogging when substantial speculations on new era and transmission offices are not inevitable[14]-[18].Past force framework arranging studies examined era also, transmission development arranging techniques in a vertically incorporated force framework. Then again, existing arranging methodologies did not consider the effect of microgrid establishments on the force framework development.

Literature review:

For reliability purpose microgrid include the distributed generations. For a reliable energy supply to their customers microgrid operators take great responsible. Due to the important of the distributed generation, these are must be noted if any system outages happens. Already we discussed in the previous studies about the analytical technique to evaluate the customer's reliability in the distribution power systems that all distributed generation are owned by one operator. The impact factor which is modified to obtain the interruption cost, fuses, photovoltaic cells are included by this proposed method.

For low voltage distribution networks we can take microgrid as best alternatives. It consists of number of distributed generators, storage devices, and controllable loads which can operate either interconnected or islanded from the main power grid. The operation of the microgrid during the interconnected operation that is maximize its value by

optimizing the production of local distributed generations and power exchanges within the main power grid are aimed by the controller. This low voltage operating networks has been applied by some developed optimization algorithms.

For reliability criterion energy storage system in a microgrid are considered. Energy storage system needs optimal size, because higher investment costs are required for larger energy storage system while microgrid operating costs are reduced. To minimize the investment costs of energy storage system, and expected microgrid operating costs, energy storage systems are must be optimized. Extensive applications in the power system operation, such as improving control, mitigating volatility and intermittency problems of renewable energy resources, load following, voltage and frequency stability, peak load management, power quality improvement, and postponement of system upgrades are proposed by energy storage system.

Distributed energy resource contains distributed generators and distributed storage. These two are the sources of energy located near the local loads. These two can provide various benefits which contain improved reliability if the local loads properly operate them in the electrical distribution system. Microgrids have one distributed energy resources and associate loads. This can form intentional island in the electrical distribution systems. By keeping the upstream switch at the point of common coupling, microgrid can disconnect the loads and energy sources from the main grid reconnect to the local electric power systems. To avoid the causing problems planning of microgrid is necessary.

Active and reactive power management is necessary in the microgrid planning. Active and reactive power management strategies are needed to be addressed in the context of multiple distributed generators microgrid system. Locally measured signals controls the distributed generators and power management strategies without communications. Voltage droop characteristics, voltage regulation, load reactive power compensation are main for the power management strategies. Frequency droop characteristics and complimentary frequency restoration strategy control the active power of each distributed generator unit. A small signal dynamic model of multiple distributed generators has been developed by a systematic approach. It presents the active and reactive power management strategies.

For improving efficiency of electrical and thermal energy consumption, an opportunity and a desirable infrastructure is provided by microgrid. The operation of various energy resources and loads must be coordinated and optimized to improve the efficiency of electrical and thermal operation. Photovoltaic and wind turbines are the renewable resources and diesel generators for typical microgrids. Batteries are considered as energy storage devices in the typical microgrids. By using all these, total cost of electrical and thermal energy must be minimized. Total cost includes the investment cost, operational cost and maintenance cost of microgrids.

Nowadays power demand is increasing year by year, at the same time transmission and distribution losses are increasing. Providing quality power and reliable power to the remote areas are the main challenges. For this, research has been started for the alternative solutions. To overcome these problems, we considered distributed generators or renewable energy resources based microgrids as the possible option. Distributed energy resources deliver the efficient and reliable power to the local areas. In a small scale frame work setup, the ideal arranging and control of the small scale framework is a key to amplifying the potential advantages of this present reality miniaturized scale framework establishment. The creators endeavour to build up an ideal outline and arranging small scale framework considering different conveyed vitality innovation alternatives, for example, sunlight based photovoltaic, little wind electric generator, biomass gasifier framework, diesel generator and battery stock piling for distinctive applications also, with reasonable inputs on their physical, working and financial qualities. The target is to turned out with numerous such ideal miniaturized scale frameworks with different blends of renewable vitality assets with ideal dispatch methodologies for diverse applications while minimizing the expenses. It displays the discoveries of the executions profiles of different small scale matrix arrangements under distinctive operational situations and additionally decides make back the initial investment separations for associating the small scale matrix with the fundamental networks.

A microgrid can expand the dependability of vitality by separating from the network on account of system blames or diminished force quality. The strategies that have been explored to control the microgrids are outlined and also those proposed to look after strength amid the moves from one mode to the next modes. The microgrid arranging structure in Shandong electric power

research institute has been introduced and talks about the different doable control methodologies utilized and present for microgrid. At that point, in light of displaying diverse sorts of appropriated eras and vitality stockpiling hardware, the Shandong electric power research institute microgrid model was mimicked with a few working modes under shared control system. The significance of a vitality stockpiling to help dependability amid move between working modes are stressed.

The use of high unwavering quality appropriation framework in the financial operation of microgrid is considered. High reliability distribution system, which offers higher operation unwavering quality and fewer blackouts in microgrids, are connected to circled systems in conveyance framework. The microgrid show in this study is made out of distributed energy resources including distributed generators, controllable burdens, and capacity. The microgrid would use the neighbourhood distributed energy resources and the primary framework for supplying its hourly load monetarily which is liable power quality and unwavering quality necessities. The high reliability distribution system executed at Illinois institute of technology is utilized as contextual analysis alongside the neighbourhood distributed energy resources to build the heap point dependability and reduction the operation expense of the Illinois institute of technology microgrid. The accessibility of circulation lines, primary network supply, and microgrid era is viewed as utilizing the Markov chain Monte Carlo simulation in the microgrid situations. The dependability lists in view of recurrence and term of blackouts are measured at the microgrid level and the heap point level, and the potential framework improvements are talked about for enhancing the financial operation Illinois institute of technology microgrid.

The possibility to enhance circulation framework dependability is an essential inspiration driving the improvement and sending of microgrids. Past studies have shown generous unwavering quality advantages of distributed energy resources. In any case, the investigation and new assessments techniques are required for microgrid commanded by constrained what's more, stochastic distributed generations. An assessment technique for islanded microgrids that practically speaks to stochastic assets and expressly inspects the impact of supply to load relationship on unwavering quality is presented. Monte Carlo simulation is utilized to model part disappointment and repair, while verifiable information is utilized for the stochastic assets. Stochastic distributed generation yield is assigned to loads in light of an

organized request that records for the dynamic reconfiguration of the microgrid on account of nearby blame. Deliberate burden diminishing also, its effect on dependability are likewise analysed.

At present, concentrated and decentralized controls are received in miniaturized scale framework. Keeping in mind the end goal to send summon data from expert controller to slave controller, concentrated control must have a high transmission capacity correspondence channel, which is not suitable to execute the distributed and attachment play control. Furthermore, when another miniaturized scale source is interconnected to the miniaturized scale lattice, the expert will need to alter all the miniaturized scale source fresh. Decentralized control is worked utilizing just neighbourhood data, yet, in the light of fact that without reference from the worldwide example, the worldwide ideal execution cannot be ensured as solidly as with worldwide controllers. A novel progressive control for smaller scale matrix is proposed. This control technique still has a certain level of decentralization anyway; likewise keep a level of centralization through a higher level control layer that controls lower level limits. The progressive control is mostly comprised of three levels: essential control, auxiliary control and tertiary control. Trial results are given to demonstrate the practicality of the progressive control technique.

Motivation:

The enthusiasm of microgrid expanded because of their capacity of improving the discernibleness and controllability of force conveyance frameworks, in this manner contributing for the diminishment of framework misfortunes, influence quality change and giving in the meantime the important conditions for expanding the association limits for diverse conveyed era advancements.

Above all the capacity of working self-ruling from the principle networks if there should be arise an occurrence of crisis circumstances expands the security of operations and lessens powerlessness of the force framework to outer assaults, coming about either from characteristics calamities (the event of the sea tempests, storms, and so forth), thought activities influencing framework security or notwithstanding coming about because of atomic occurrences.

The crisis method of operation obliges sufficient control and administration frameworks to give a stable islanded operation or to generally misuse an administration rebuilding strategy in the coming of a general power outage. In these circumstances, the extra stockpiling limit given by the EV can help in the regulation recurrence and voltage.

2. CHAPTER

Objective of the work:

- To minimize the total power loss in the system by using the distributed generators
- To get the optimal location of the distributed generators by using the optimization technique

2.1 Distributed generators:

Late years have seen a pattern towards the advancement also, sending of dispersed era (DG) because of government approach changes and expanded accessibility of little limit era innovations. The way of circulated era littler plant (under 100MW) with little or restricted focal control, joined with the circulation framework. Conveyance frameworks have been generally intended to work with unidirectional force stream, from the source (transmission framework) to the heaps. Adding distributed generators to a dissemination framework forces an alternate set of working conditions on the system, for example, reverse force stream, voltage rise, expanded issue levels, lessened power misfortunes, symphonies contortion and soundness issue.

The vicinity of extra era on a feeder might likewise take into account remain solitary, island mode operation where distributed generators are supplying bits of the feeder stack after a shortcoming has been segregated. Islanded operation, nonetheless, requires critical coordination of dispersed generators with feeder insurance gadgets keeping in the mind the end goal to make conceivable self-supporting islands. For each operation arranging framework investigating is required for dispersed era coordination to be effective from both framework security and unwavering quality perspective.

Uniting a distributed generator source to the conveyance framework must be done so as working conditions are kept inside of given limits. Plainly, the impact of including distributed generator system security furthermore, dependability will differ contingent upon its write and position furthermore, load at the association point. Subsequently one or more locals on a given system may be ideal. Notwithstanding generally couple of generators being associated with the system at present, improvement of circulated era is not envisaged to be midway arranged or worked. With this as a main priority, distributed generators ought to be

presented for general framework advantage, particularly if the framework exists to give reinforcement limits. On the off chance that an ideal siting system is looked for, motivating force project may be considered with a specific end goal to encourage usage of distributed generators in the attractive locations. On the other hand, extra charges might be forced for distributed generators set so to bring about issues and lower framework execution.

Preparatory studies have as of now demonstrated that unless reinforcement limit is given, remain solitary appropriated era may lower framework dependability. Likewise, it could hurt framework dependability in the event that it is not legitimately composed, found and intended to work with the existing system security. In a spiral feeder, assurance gadgets are just anticipated that would distinguish unidirectional stream of current. In a larger part of cases, stand out gadgets works every issue. The control rational for security gadgets subsequently is straightforward the closest reclosed upstream from the issue area distinguishes the issue current, trips, and goes into a predefined reclosing succession to restore administration, in case the issue was of an impermanent nature. In the event that more reclosers are available on the outspread feeder, they are facilitated, typically by means of time slacks, such that reclosers nearest to the shortcoming work. In distributed generators upgraded feeder, force stream is most certainly not unidirectional and routine assurance rational must be modified all together for the issue distinguishing gadgets to effectively perform their capacity. A blamed branch may be stimulated from both sides and a few security gadgets may need to work with a specific end goal to totally intrude on the shortcoming current. A few control methods, utilizing just neighbourhood or SCADA estimations, may be used. Appropriated era and capacity units, situated on the feeder might power and vitality restricted, and may incorporate renewable distributed generator, whose yield is subject to the meteorological conditions. Those sources may decrease the quantity of issues also, or issue lengths of time for clients inside of their security zones, in this manner expanding the dependability of administration.

The accompanying related streamlining assignments may be researched: (a) improve recloser position for a given distributed generator allotment, (b) streamline distributed generator situation for a given recloser allotment and (c) streamline both recloser and distributed generator situation. The ideal recloser arrangement is fathomed for a beforehand decided ideal position of the distributed generators. Both voltage affectability examination and misfortune affectability

examination of the influence stream mathematical statements are utilized to focus the ideal destinations for arrangement of appropriated generators. It is trailed by a security compelled advancement technique which figures the amount of distributed generators that can be associated with indicated focuses with the framework staying secure. The appraisal considers the conveyed asset force component qualities and burden profile for different working conditions. The data on the ideal era destinations is utilized further to upgrade frame work dependability evaluated through count of unwavering quality lists which incorporate the distributed generators. A differential evolutionary algorithm is intended to illuminate for ideal recloser position when the distributed generators are sent in a safely ideal way.

The presentation of creating sources into the circulation framework can essentially affect the working state and flow of both the transmission and distribution frameworks. While at low or humble levels of distributed generator entrance, the effects on the high voltage transmission framework may not be critical, sways at the low voltage distribution level could be much bigger particularly as for shortcoming currents levels, the greatness and heading of genuine and respective force stream, the framework voltage (both consistent state and transient) and the framework steadiness under different little and extensive transient conditions. The effects and associations can be both positive furthermore, negative contingent upon the circulation system working qualities and the circulated era trademark, arrangement and size. A fitting arrangement plays an extremely vital part since force stream at the interface substations what's more, all through the system rely on upon geographic conveyance of all era sources regarding interest independent of the voltage association point. For conveyed era to have a beneficial outcome, it must be at minimum suitably coordinated and facilitated with the appropriation framework working practices and feeder outline. With a specific end goal to further the beneficial outcome and improve system limit cut-off points while adding to framework security and nature of supply, neighbourhood improvement would be obliged went with exploiting any inalienable regulation ability of scattered era.

So the expansion of distributed generation will more often than not bring about changes in voltage extents and force streams. These progressions will influence framework misfortunes. These are clear ramifications for the current ratings of lines coming about because of adjusted force streams; also, voltage changes could see voltages ascend to undesirable levels.

Generators working with a main force variable may exacerbate the last. Likewise, distributed generators infused force may bring about voltage that is inside of breaking points at the distributed generators site however could be out of cut off points further downstream. The expansion of additional force sources to a system likewise effects on framework issue levels and may blame stream increment past the rating of circuit breakers. The embodiment is that including generators to uninvolved appropriation framework make it dynamic appropriation framework, like to a smaller than usual transmission framework, and additional thoughts must be given to its operation and control. All the more particularly, in voltage profile and regulation studies, accessible transmission limit studies, and cost examines, the association point, sort, size and area of distributed generators, the voltage control settings and freedom qualities of the line should be considered for different loads and burden thickness levels.

Ideal position distributed generators for upgraded unwavering qualities decreased transmission and circulation costs and diminished emanations can be acknowledged just by considering all components, including the misfortune diminishment accomplished framework wide and on the feeders, security limits furthermore, cost or advantage examination. It is an extremely complex issue considering a high number of choices regarding locals and units accessible and need to record for a 8760 h load profile and era profile and related vulnerabilities. The OPF-based ideal arrangements are proposed tending to the impact of distributed generators on the spot costs and strength limits. Other studies have handled the ideal situation issue utilizing hereditary calculation strategies or tabu or parallel tabu seeks. These strategies shift in many sided quality and processing time, to actualize and oblige some levels of cost information. The tabu pursuit specifically is computational concentrated. In this study, expenses identified with including the distributed generators and transmissions or conveyance redesigns or funds definitely not considered and the system limit points of confinement are assessed in the light of the effects of appropriated era on framework misfortunes, security and sufficiency of supply.

Keeping in mind the end goal to focus the most suitable destinations for distributed generators, two affectability based methodologies identified with voltage control and power misfortune are proposed. Both the affectability file and misfortune affectability file are characterized and utilized to distinguish and rank the hubs inside of the system with appreciation

to accepting new era. It is expected that generators can join with any point in the system subject to security limitations and are not confined in their area by generators controllers or existing insurance gadgets.

2.2 Impact of distributed generation

Circulation frameworks are outlined on the suspicion that electric force streams from the force framework to the heap. In this way, if yield vacillations or an opposite stream from generators happens on the matrix on the view of distributed generation, there is likely to be some impact on the general framework regarding force quality or security and wellbeing. The potential effects of distributed generations are:

2.2.1 Power security

(a) Increase in short circuit current: at the point when short out flaw happens, shortcoming current is supplied from the both power framework and distributed generation to the flaw point. On the off chance that the aggregate issue current surpasses the limit of the feeder's circuit breaker, the issue cannot be isolated out, thus proceeds.

(b) Deterioration of affectability of blames: contingent upon the area of the issue, the affectability of the hand off framework is at risk to disintegrate. Flaw current declines on the feeder at the substation by supplying flaw current from distributed generation. For this reason, the hand off framework either will be unable to distinguish the shortcoming or may be ease back to recognize it.

2.2.2 Power quality

(a) Excess voltage: the voltage of substations of conveyance lines is controlled by a modified clock or line drop compensators. For the most part, the solitary appropriation transformer has a few feeder lines, and the voltage for these lines is balanced in a piece. Also, a SVRremunerates the voltage mid path along the line in the substantial force stream or long transmission lines. The heap of each feeder ought to be adjusted relatively to use these voltage control frameworks. In the event that there are numerous distributed generators associations focused on a particular line, the hole in the force stream among the feeder lines extends due to the reverse from the

distributed generators. This distinction may bring about the voltage profile of feeder lines to digress from the correct reach.

(b) Voltage change: the voltage of the nearby framework is prone to change if the yield of the distributed generators changes more than a short time, and this change would bring about over or under voltage at the clients accepting point. There is specific concern when creating framework that depend on characteristic conditions, for example, wind power or sunlight based photovoltaic generators, are interconnected to the neighbourhood framework.

2.2.3 Reliability

Distributed generators could have a positive effect on dissemination framework unwavering quality on the off chance that they are accurately facilitated with whatever remains of the system. A typical sample of distributed generators utilization is as era reinforcement, in which the unit works on account of fundamental supply interference. A distributed generator application that is picking up fame is the infusion of force into the system when the distributed generator limit is higher than its neighbourhood loads. A common illustration is a cogeneration plant, where the distributed generator proprietor is changed just for the distinction between the vitality depleted from the conveyance utility and the sum infused into the system. At the point when the distributed generator is working in parallel with the framework, new contemplations are presented in the system operation and arranging techniques. A basic distinct option for model distributed generators is as consistent dynamic and receptive force infusions free of the framework voltage at the unit terminal transport. The distributed generator model of negative burden can have a positive effect in framework dependability if the dependability assessment model considers limit imperatives amid framework rebuilding after a flaw. Another option is to model distributed generator units as controlled voltage sources in which the terminal voltage kept up at steady esteem by receptive power infusion. Under this condition, it ought to be kept away from to regard all distributed generation sources as accessible for dispatch by the utility at whatever point vital, since the distributed generator s are not so much property of the dissemination utility. This issue can be understood by displaying greatest measure of the dynamic force dispatch able by the unit and the periods when it will be accessible.

2.2.4 Losses and voltage profile

Distributed frameworks are normally voltage controlled through tap changing at substation transformers and by the utilization of voltage controllers and capacitors on the feeders. This type of voltage regulation expect force stream flowing from the substations to the heaps. Distributed generators presents switched force streams that may meddle with the generally utilized regulation rehearses. Consequently, the wrong distributed generator designation can bring about lower or over voltages in the system. On the other hand, the establishment of distributed generator can have positive effects in dissemination framework by empowering responsive pay, the voltage control, lessening of misfortunes, other than adding to recurrence regulation and giving turning save in primary framework deficiency cases. An exact method for examining the voltage regulation of framework with implanted distributed generators is through recreation utilizing force stream calculations fit for breaking down different well springs of distributed generator together with the operation of voltage controllers. In this examination, it is critical to perceive that the force infused by the distributed generator unit can bring about the voltages inside of as far as possible at distributed generator establishment site, yet, it could, likewise, bring about undesired values at the different part of the feeder.

Distributed generation likewise gives positive effect in electric misfortune because of its vicinity of load focuses. Distributed generation units ought to be dispensed in places where they give a higher diminishment of misfortunes. This procedure of distributed generation allotment is like capacitor portion to minimize misfortunes. The primary contrast is that the distributed generation units bring about effect on both the dynamic receptive force, while the capacitor bank just has effect in the receptive force stream. Shockingly, the electric vitality utility does not have supreme control of the establishment places, since the distributed generation is more often than not of customer's or free makers property. Notwithstanding that it is of extraordinary enthusiasm for the utility to utilize a procedure for ideal distributed generation portion so as to have an evidence of the impacts brought about in the framework by the area recommended by the autonomous makers.

The assessment of every potential arrangement is made through a force stream programme for appropriation systems with the representation of different generators the strategy received in this work is in the light of force summation technique with every distributed generation unit is spoke to by PV bus with indicated voltage greatness. The

representation of PV buses in outspread frameworks force stream models suggest in the production of system breakpoints, where the voltages of the buses (terminal and imaginary) ought to be kept up at the same determined module. At every emphasis, the voltage jumbles between two sides of the breakpoint is figured what's more, receptive force infusions are figured so as to right the voltage confound. This procedure proceeds until the voltage confound is not as much as a resistance.

The essential vitality on which the distributed generation based has central impact on the unwavering quality. Units taking in to account non irregular and storable sources can be more effectively spoke to, since its vitality is displayed for unwavering quality reason as constantly accessible. The main conceivable reason for distributed generation power era inaccessibility is the disappointment of the unit, which can arbitrarily happen. The kind of distributed generation unit has a tendency to be more dependable. Then again, units taking into account irregular and non-storable sources, oblige a model in which the essential vitality accessibility must be likewise spoken to. The distributed generation power inaccessibility displaying as a rule requires the examination of the essential source enrolment time arrangement (wind speeds, sunlight based occurrence, and so forth) more than quite a while. The distributed generation power era is at that point displayed by blend of the vitality and the unit accessibility models.

In the philosophy executed in this work, the distributed generation vitality source is considered constantly accessible. Despite that the model does not consider the vulnerability identified with force accessibility, which is needed for wind or sunlight based vitality based sources, it is satisfactory for gas and diesel based advancements, which are in effect generally utilized for distributed generation units. Diesel motors changed over from boat or car motors are in boundless use as a primary force source. Gas turbine establishments are found essentially in buyer utilization and expansive scale commercial ventures, which may be associated with essential appropriation system. In the present strategy, the distributed generation is demonstrated correspondingly to back feed with exchange requirements equivalent to the distributed generation unit limit. The heap piece dependability records are figured contrasting the piece introduced burden and the aggregate limit of distributed generation straightforwardly joined with the piece. On the off chance that the distributed generation limit is higher than the

heap, the heap square inaccessibility span is just the time for separating the shortcoming and re-joining the distributed generation. Something else, the square inaccessibility span will be the repair time of the fizzled segment.

2.3 NEWTON RAPHSON METHOD

The condition of a force framework and the routines for computing this state are critical in assessing the operation and control of the force framework and the determination of the future extension for thus framework. The condition of any force framework can be resolved utilizing burden stream examination that computes the force coursing through the lines of the framework. There are diverse techniques to focus the heap stream for a specific framework, for example, gauss-seidel method, and NewtonRaphson method.

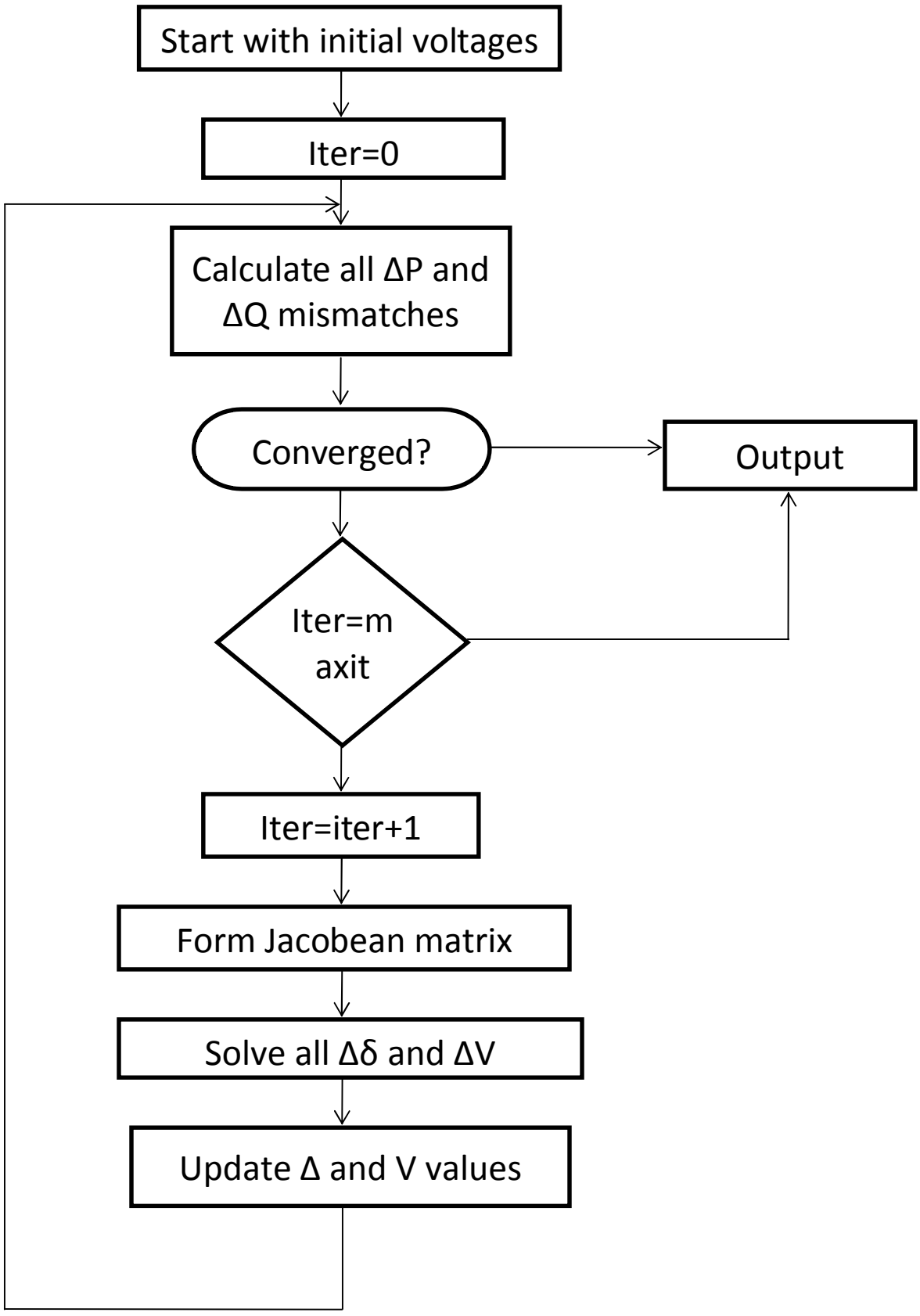
In the course of recent year, improvements have been made in discovering advanced PC arrangements for force burden streams. This includes expanding the unwavering quality and the velocity of union of the numerical arrangements strategies. In normal utilization, even couple disappointments to give first time union for physically practical issues can be uneconomical. Thus, the Newton Raphson methodology is the most favoured general system. The attributes and execution of transmission lines can fluctuate over wide breaking points essentially subject to their framework. Consequently the Newton Raphson strategy is utilized to keep up a worthy voltage profile at different buses with changing force stream.

The primary motivation behind the heap stream arrangements is to assess the individual stage voltage by any means bus bars associated with system comparing to indicated framework conditions. As the real and reactive powers, voltage extents, and angles are include for every bus four free limitations are obliged to settle for the fore mentioned four questions parameters. There are two fundamental sorts of buses that are generator and load buses. An extraordinary sort of generator bus is utilized as reference bus is nothing but slack bus. For diverse sorts of buses the limitations are diverse.

The Newton Raphson methodology is the most favoured burden stream strategy due to its different preferences. It has effective meeting attributes contrasted with option forms also, impressively low processing times are accomplished when the inadequate system comparisons are explained by the procedure of sparsely-customized requested end. The Newton

Raphson methodology especially helpful for vast systems as PC stockpiling prerequisites are moderate and increment with issue estimate directly. The system is extremely touchy to a decent beginning condition. The utilization of a suitable beginning condition decreases the calculation time strikingly, and additionally guarantees the joining. No quickening components must be resolved, the decision of the slack bus is infrequently discriminating, and system adjustment require less figuring exertion. The Newton Raphson technique has awesome sweeping statement and adaptability, consequently empowering an extensive variety of representational prerequisites to be incorporated effectively and productively, for example, on load tap changing furthermore, stage moving gadgets, range trades, utilitarian burdens and remote voltage control. The Newton Raphson method burden stream is fundamental to numerous as of late created strategies for the improvement of force framework operation, affectability examinations, framework state estimation, straight system demonstration, security assessment and transient solidness examination, and it is appropriate to online calculation.

2.3.1 Flow chart for Newton Raphson method:



2.3.2 Newton Raphson application to power flow

We first need to rewrite complex power equations as equations with real coefficient

$$S_i = V_i I_i^* = V_i\left(\sum_{k=1}^{n} Y_{ik} V_k\right) = V_i \sum_{k=1}^{n} Y_{ik}^* V_k^* \qquad \ldots\ldots (2.1)$$

These can be derived by defining

$$Y_{ik} = G_{ik} + jB_{ik}$$
$$V_i = |V_i| e^{j\theta_i} = |V_i| \angle \theta_i$$
$$\theta_{ik} = \theta_i - \theta_k$$
$$e^{j\theta} = \cos\theta + j\sin\theta$$

Real power balance equations

$$S_i = P_i + jQ_i = V_i \sum_{k=1}^{n} Y_{ik}^* V_k^* = \sum_{k=1}^{n} |V_i||V_k| e^{j\theta_{ik}} (G_{ik} - jB_{ik}) = \sum_{k=1}^{n} |V_i||V_k| (\cos\theta_{ik} + j\sin\theta_{ik})(G_{ik} - jB_{ik})$$

…… (2.2)

$$P_i = \sum_{k=1}^{n} |V_i||V_k| (G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik}) = P_{Gi} - P_{Di} \qquad \ldots\ldots. (2.3)$$

$$Q_i = \sum_{k=1}^{n} |V_i||V_k| (G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik}) = Q_{Gi} - Q_{Di} \qquad \ldots\ldots. (2.4)$$

In the Newton Raphson power flow we use Newton's method to determine the voltage magnitude and angle at each bus in the power system to satisfy the power balance. We need to solve the power balance equations:

$$\sum_{k=1}^{n} |V_i||V_k| (G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik}) - P_{Gi} + P_{Di} = 0 \qquad \ldots\ldots\ldots. (2.5)$$

$$\sum_{k=1}^{n} |V_i||V_k| (G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik}) - Q_{Gi} + Q_{Di} = 0 \qquad \ldots\ldots\ldots. (2.6)$$

For convenience, write:

$$P_i(X) = \sum_{k=1}^{n} |V_i||V_k| (G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik}) \qquad \ldots\ldots\ldots.. (2.7)$$

$$Q_i(X) = \sum_{k=1}^{n} |V_i||V_k| (G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik}) \qquad \ldots\ldots\ldots.. (2.8)$$

Power equations are then:

$$P_i(X) - P_{Gi} + P_{Di} = 0 \qquad \ldots\ldots\ldots\ldots (2.9)$$

$$Q_i(X) - P_{Gi} + P_{Di} = 0 \qquad \ldots\ldots\ldots\ldots (2.10)$$

Assume the slack bus is the first bus (with a fixed voltage magnitude and angle)we then need to determine the voltage angle and magnitude at other buses we must solve f(X) =0, where:

$$X = \begin{bmatrix} \theta_2 \\ - \\ - \\ - \\ - \\ \theta_n \\ |V_2| \\ - \\ - \\ - \\ - \\ V_n \end{bmatrix} \qquad \ldots\ldots\ldots\ldots (2.11)$$

$$f(X) = \begin{bmatrix} P_2(X) - P_{G2} + P_{D2} \\ - \\ - \\ - \\ P_n(X) - P_{Gn} + P_{Dn} \\ Q_2(X) - Q_{G2} + Q_{D2} \\ - \\ - \\ - \\ Q_n(X) - Q_{Gn} + Q_{D2} \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\ldots (2.12)$$

The power flow is solved using the procedure discussed previously for general equations

For V=0, make initial guess of X

While $\left\| f(X^{(v)}) \right\| \rangle \in$

$X^{(v+1)} = X^{(v)} - [J(X^{(v)})]^{-1} f(X^{(v)})$

End $V = V + 1$

3. CHAPTER

Differential evolution algorithm

3.1 Introduction

Differential Evolution (DE) is a modestly current trial mode (this was shaped in the centre 1990s) opposite by Kenneth Price and Rainer Storn, which was reason to build issues above unbroken domains. This procedure fortifies from Kenneth's Price efforts to arrangement the Tchebycheff Polynomial getting to be Problem that had been settled to him through Rainer Storn. In one of the particular choose to determine this recommendation, the contriver came up by the judgment of worn vector refinement for uneasy the vector populace. Over its administration, the algorithmic principle was more improve and refined, after unnumbered dispute among Price and Storn. DE is a frank chase transformative algorithmic tenet which has been often utility to arrangement broadened enhancement bug. DE profits similarities by routine EAs. In spite of the fact that it doesn't use double encoding as a simple hereditary calculation and does exclude likelihood thickness capacity to auto-adjust its requirements as an Evolution Strategy. As an option, DE arrangements transformation based on the conveyance of the outcomes in the present populace. Consequently in DE, research headings and likely step sizes hold tight the area of the people chose to gauge the transformation values.

A details plant has been enhanced to look the disparate DE options. The most extreme prevalent of them is assign "DE/rand/1/bin", wherever "DE" advert Differential Evolution, the dialect "rand" specify that people assigned to consider the change qualities are choose at achieve, "1" betoken the huge number of twofold of arrangements recruit and all in all "bin" subjugated that a binominal name recombination is propensity.

The "CR" highlight neutralizes the control of the guardian in the era of the posterity. More prominent worth of "CR" recognizing implies less after effect of the guardian. The "F" highlight connect with the control of the arrangement of flight of arrangements describe to figure the transformation esteem.

One of the profound actualities can be sickle either the populace swell or the quantity of hinder of answers for number the transformation qualities may disturb the kind of likely courses of action, propel the pursuit of the pry into meander. On the other ability, the likeliness to development the change test clew rots basically. At that point, the harmony among the populace gage and the quantity of change is custom to discover the adequacy of the algorithmic project. Other than this weigh, extra genuine constituent while append DE is the citation of the variable. All concoction component swerve the transformation is figure and on the insignia of recombination theorist need.

A complete collection of DE substitutes are possible. To recognized this minute, the start respect the work done by Mezura et al. and interest eight DE variations, independently of which are to be briefly complete serially. The adjustments from distinctive to variable are in the recombination examiner custom furthermore in the parade people are decided to arrange the change vector .The variations affirmed by Mezura et al. are sharp as beneath:

- Four varieties whose recombination theorist is prominent, constantly second-hand two people: the birthplace source and the DE change vector. Two intermittent recombination administrators: binomial and exponential. The capital controversy between them is that for species name recombination, every precarious worth of the ancestry is taken at each age from one of the two bring about, bolstered on the "CR" recognizing glow. On the

other office, in the exponential recombination, every drifting respect of the family is taken from the first creator until an achieve numeral top the "CR" significance. From right now, all the heredity capricious brilliance will be taken from the guide source. These variations are:

1. DE/rand/1/bin (classic DE)

2. DE/rand/1/ - exp

3. DE/best/1/bin

4. DE/best/1/exp

The "rand" varieties picked all the people to rate change at speed and the "most noticeably awful" varieties custom the prime discharge in the populace too the viciousness once.

- Two varieties with math recombination, which, impossible disjunction recombination, is upheaval constant. These are "DE/current-to-rand/1" and variably "DE/current-to-best/1". The main challenge among them is that the principally pick the people for change at subjective and the subordinate one uses the pick clarification in the populace likewise discretionary arrangements.
- "DE/rand/2/dir", which otherworldly reasonable obligation educating to the transformation and recombination agents. The plan of this strategy is to direct the attempt to promising degrees snappier than customary DE. Their originator debate that the best result is keep when the significant number of flight of arrangements is two.
- In conclusion, an alternate by a confederated spasmodic qualifier recombination, the "DE/current-to-rand/1/receptacle".

3.2Method for differential evolution

Differential Evolution is a parallel direct inquiry technique which makes utilization of NP parameter vectors

$X_{i, G}$, i=0, 1, 2…….. …….. (3.1)

G is the generation population

NP is the population size

The beginning populace is chosen arbitrarily if nothing is thought about the framework. We will accept likelihood dispersion to be uniform for all arbitrary choice unless generally expressed. On the off chance that a preparatory arrangement is accessible, the ordinarily circulated irregular deviations is added to the ostensible arrangement, Xnom,0 to produce the beginning arrangement. The pivotal thought behind DE is a strategy to create trial parameter vectors. A weighted distinction vector between two populace individuals is added to a third part to create another parameter vector. On the off chance that the subsequent test vector yields a lower target capacity than a current populace part, the test vector will supplant the current vector with which it was thought about in the accompanying era. The test vector could possibly be a piece of the era process. Likewise the best parameter vector Xbest,G is figured out for each era with a specific end goal to stay informed concerning the advancement occurring amid the minimization process.

For every vector $X_{i,G}$, $i = 0,1,2,.....NP-1$

The trial vector produced is

$V=X_{r1, G}+F*(X_{r2, G}-X_{r3, G})$ ……. (3.2)

$r1, r2, r3 \in [0, NP-1]$ Are integers and mutual dependent, and F should be greater than zero

The whole numbers r1, r2 and r3 are arbitrarily browsed the interim [0, NP-1] and are not same as the running record i. F is a genuine variable and is consistent. It controls the enhancement of differential vector.

To expand the differing qualities of the parameter vector, the vector

$U= (U_0, U1, U2 \ldots U_{D-1})^T$ ……. (3.3)

With $U_j = V_j$ for j=‹n›D, ‹n+1›D…‹n+L-1› …….. (3.4)

$(X_{i,G})_j$ For all other $j \in [0, D-1]$

Where $\langle\rangle D$ indicates the modulo function with modulus D.

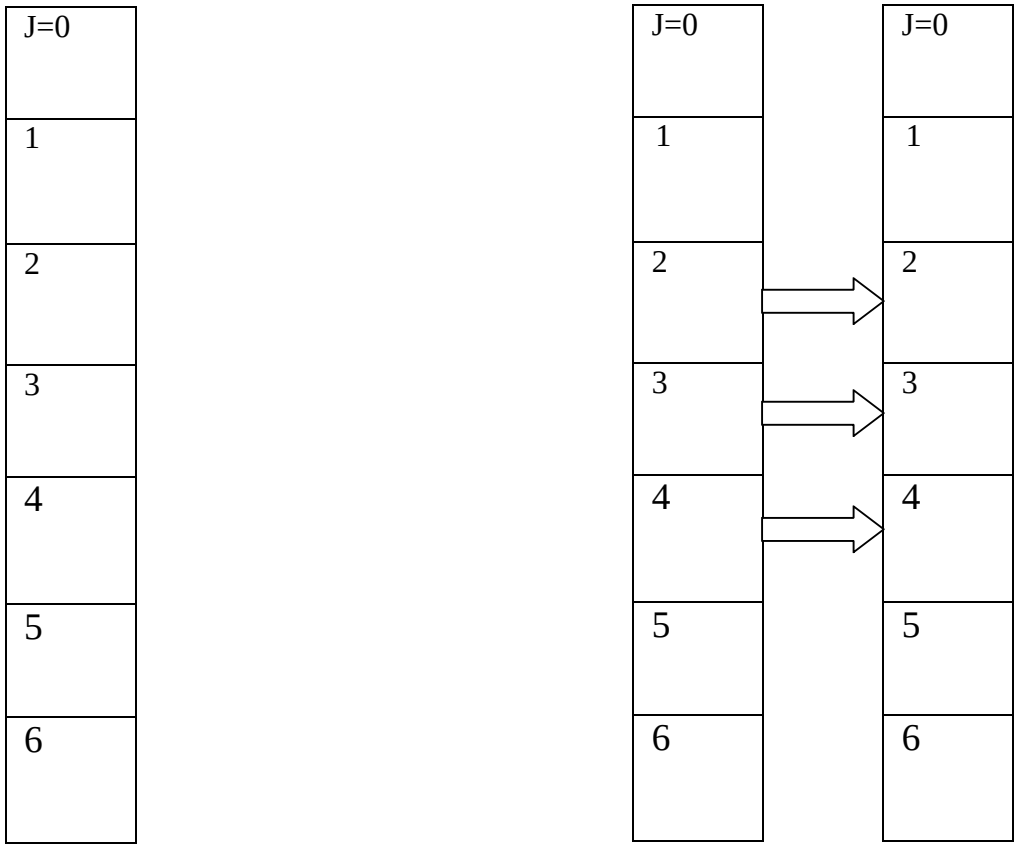
The above mathematical statements bring about certain succession of the vector components of U to be indistinguishable to that of V, alternate components of U take up the first estimations of Xi,G. The thought is shown in the figure given in the following page for D=7, n=2 and L=3. The beginning record n is picked arbitrarily from the interim [0, D-1]. The whole number L signifies the quantity of parameters to be traded. It is chosen from the interim [1, D]. The calculation that decides the working of L as indicated by the accompanying lines of code rand (), which creates an arbitrary number from [0, 1].

```
L=0;
Do {
    L=L+1
```

}

While {rand () <CR AND (L<D)}

$X_{i,G}$ $V = X_{1,G} + F*.(X_{r2,G} - X_{r3,G})$ U



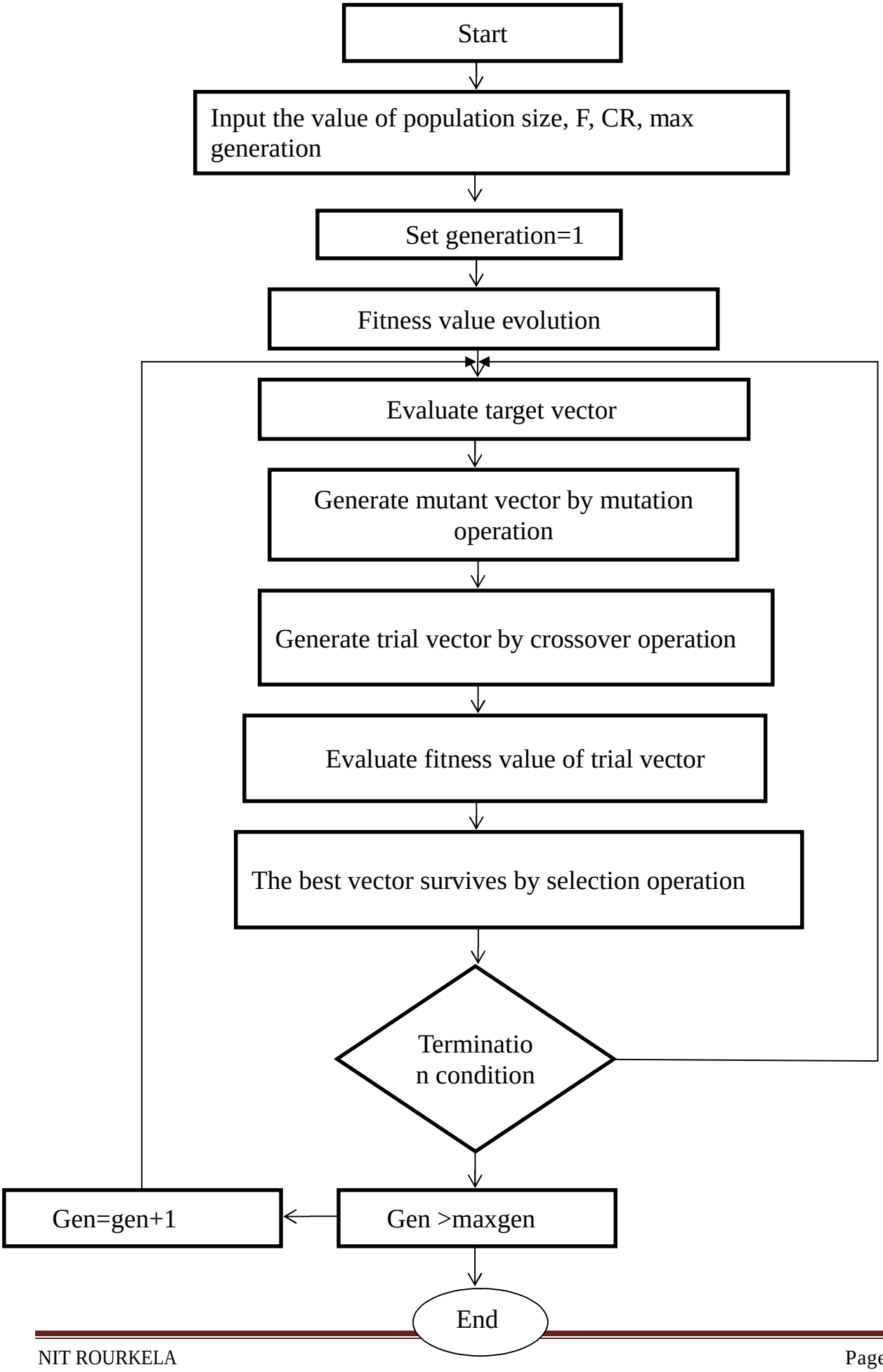
Vector joining parameter

Parameters $X_{j,}$ j=0, 1, 2 ...D-1

Figure 3.1 mutation of differential evolution

So as to check if the new vector U turns into the individual from era G+1, it is contrasted with Xi,G. In the event that the vector has a littler capacity esteem than Xi,G, Xi,G+1 is situated to U, generally the prior quality is held.

3.4 Flow chart for differential evolution algorithm


Start
Input the value of population size, F, CR, max generation
Set generation=1
Fitness value evolution
Evaluate target vector
Generate mutant vector by mutation operation
Generate trial vector by crossover operation
Evaluate fitness value of trial vector
The best vector survives by selection operation
Terminatio n condition
Gen=gen+1
Gen >maxgen
End

4. CHAPTER

SIMULATION RESULTS AND ANALYSIS

4.1 Simulation results

30 BUS SYSTEM:

5	19	27	30	9	29	52	52	52	52	52	0.8

LOCATIONS ⟵ ⟶ CAPACITY ⟵ ⟶

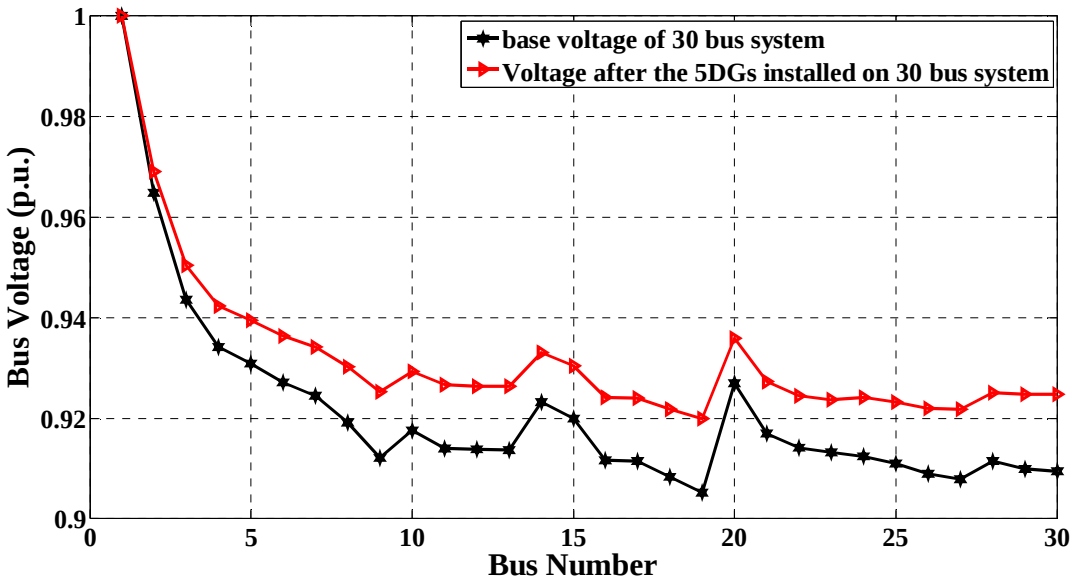
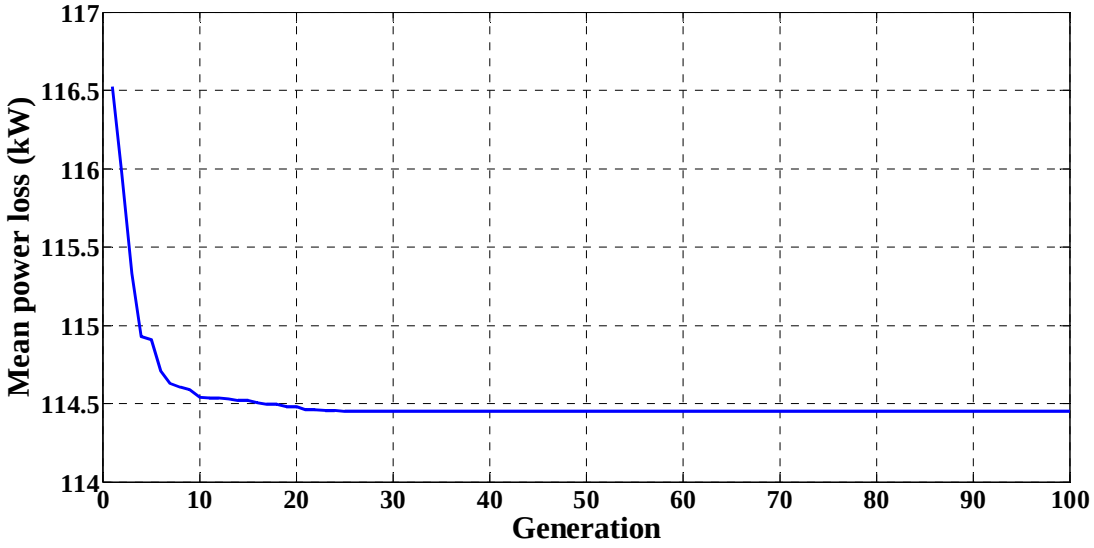


Fig 4.1 voltage versus bus number for 30 bus system



Figs 4.2 mean power loss versus generation for 30 bus system

52 BUS SYSTEM

5	51	50	51	44	19	84	84	84	84	84	0.8
	LOCATIONS					CAPACITY					

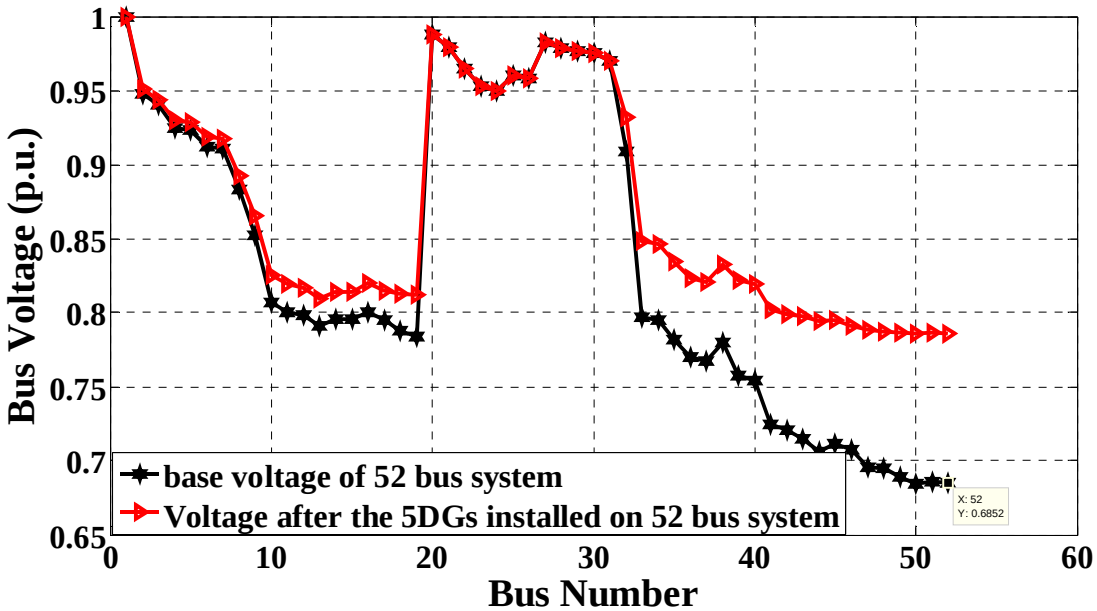
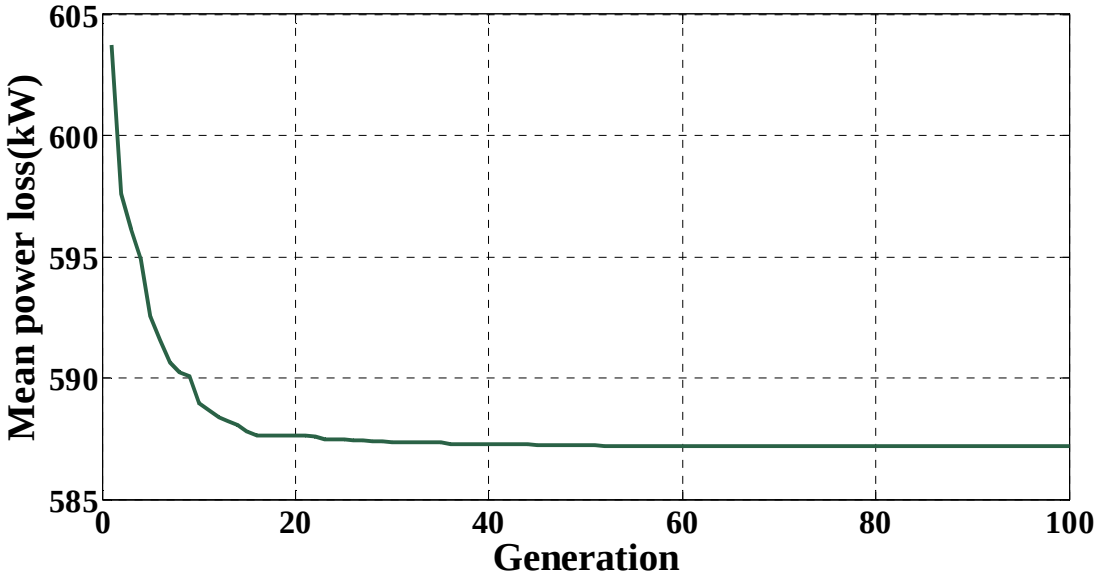


Fig 4.3 voltage versus bus number for 52 bus system



Figs 4.4 mean power loss versus generation for 52 bus system

4.2Analysis:

Newton Raphson load flow method is applied to get the voltage magnitude, load angle, active power, and reactive power at each bus in the system. We get the power loss in the system by using Newton Raphson method. This power loss is minimized by placing some distributed generators randomly in the system. To get the minimum power loss by using distributed generators, optimization technique is needed. By applying the optimization technique, we get the optimal values by minimizing power loss. Differential evolution algorithm optimization technique is used to minimize the power loss and to get the optimal values. The distributed generator's locations are taken randomly with constant capacity. This optimization technique is applied for both 30 bus system and 52 bus system.

For 30 bus system:

Without DG:

Power loss=147.0750kW

Voltage at end node=0.9094V

With DG:

Power loss=118.1654kW

Voltage at end node=0.9248V

For 52 bus system:

Without DG:

Power loss=887.4005kW

Voltage at end node=0.6852V

With DG:

Power loss=565.8369kW

Voltage at end node=0.7857V

5. CHAPTER

5.1CONCLUSION

The power loss is minimized by using distributed generators in both 30 bus system and 52 bus system. Optimal locations for distributed generators with constant capacity are obtained by using differential evolution algorithm optimization technique. Voltage improvement is also occurred at each bus in both 30 bus system and 52 bus system.

5.2Future scope

Minimize the aggregate framework arranging expense involving venture expense and operation expense of neighbourhood microgrids in the transmission arranging.

5.3References

[1] M. Shahidehpour, “Role of smartmicrogrid in a perfect power system,” in Proc. IEEE Powerand Energy Society General Meeting, 2010.

[2] A. Flueck and Z. Li, “Destination perfection,” IEEE Power Energy Mag., vol. 6, no. 6, pp. 36–47, Nov./Dec. 2008.

[3] M. Shahidehpour and J. Clair, “A functional microgrid for enhancing reliability, sustainability, and energy efficiency,”Electr. J., Oct. 2012.

[4] S. Bahramirad, W. Reder, and A. Khodaei, “Reliability-constrained optimal sizing of energy storage system in a microgrid,” IEEE Trans.Smart Grid, accepted for publication.

[5] N. Hatziargyriou, H. Asano, M. R. Iravani, and C. Marnay, “Microgrids: An overview of ongoing research, development and demonstration projects,” IEEE Power Energy Mag., vol. 5, no. 4, pp. 78–94, July/Aug. 2007.

[6] A. G. Tsikalakis and N. D. Hatziargyriou, “Centralized control for optimizing microgrids operation,” IEEE Trans. Energy Convers., vol. 23, no. 1, pp. 241–248, Mar. 2008.

[7] B. Kroposki, R. Lasseter, T. Ise, S. Morozumi, S. Papathanassiou, and N. Hatziargyriou, “Making microgrids work,” IEEE Power EnergyMag., vol. 6, no. 3, pp. 40–53, May 2008.

[8] I. Bae and J. Kim, “Reliability evaluation of customers in a microgrid,” IEEE Trans. Power Syst., vol. 23, no. 3, pp. 1416–1422, Aug. 2008.

[9] M. Khodayar, M. Barati, and M. Shahidehpour, “Integration of high reliability distribution system in microgrid operation,” IEEE Trans.Smart Grid, to be published.

[10] S. Kennedy and M. Marden, “Reliability of islanded microgrids with stochastic generation and prioritized load,” in Proc. IEEE Powertech, Bucharest, Jun. 2009.

[11] F. Katiraei and M. R. Iravani, “Power management strategies for a microgridwith multiple distributed generation units,” IEEE Trans. PowerSyst., vol. 21, no. 4, pp. 1821–1831, Nov. 2006.

[12] C. Hou, X. Hu, and D. Hui, “Hierarchical control techniques applied in micro-grid,” in Proc. IEEE Conf. Power Syst. Tech. (POWERCON), Hangzhou, China, Oct. 2010.

[13] A. G. Tsikalakis and N. D. Hatziargyriou, “Centralized control for optimizing microgrids,” IEEE Trans. Energy Convers., vol. 23, no. 1, pp. 241–248, 2008.

[14] M. Shahidehpour, “Global broadcast - transmission planning in restructured systems,” IEEE Power Eng. Mag., vol. 5, no. 5, pp. 18–20, Sep./Oct. 2007.

[15] S. de la Torre, A. J. Conejo, and J. Contreras, “Transmission expansion planning in electricity markets,” IEEE Trans. Power. Syst., vol. 23, no. 1, pp. 238–248, Feb. 2008.

[16] M. Shahidehpour, H. Yamin, and Z. Y. Li, Market Operations in Electric Power Systems. New York: Wiley, 2002.

[17] O. B. Tor, A. N. Guven, and M. Shahidehpour, “Congestion-driven transmission planning considering the impact of generator expansion,” IEEE Trans. Power Syst., vol. 23, no. 2, pp. 781–789, May 2008.

[18] Federal Energy Management Program, Using Distributed Energy Resources, a How-To Guide for Federal Facility Managers, U.S. Department of Energy, DOE/GO-102002-1520, May 2002.

Appendix

Bus data for 30 bus system

Bus no.	P_L	Q_L
1	0	0
2	162	96
3	150	138
4	12	7.2
5	30	18
6	45.6	33.6
7	12	6
8	18	14.4
9	156	120
10	48	36
11	64.8	36
12	36	18
13	12	6
14	48	36
15	36	24
16	26.4	14.4
17	12	6
18	48	48
19	96	72
20	32.4	24
21	96	84
22	54	46.8
23	30	24
24	24	12
25	30	24
26	48	36
27	48	36
28	120	108
29	72	36
30	36	36

Line data for 30 bus system

From bus	To bus	R	X_L
1	2	1.632	1.1019
2	3	1.088	0.7346
3	4	0.544	0.3673
4	5	0.272	0.1836
5	6	0.544	0.3673
6	7	1.376	0.3896
7	8	2.752	0.7792

8	9	4.128	1.1688
4	10	3.6432	1.5188
10	11	0.9108	0.3797
11	12	0.4554	0.1898
12	13	0.4554	0.1898
11	28	1.376	0.3896
28	29	1.376	0.3896
29	30	4.128	1.1688
5	20	0.9108	0.3797
20	21	1.8216	0.7594
21	22	2.7324	1.1391
22	23	0.9108	0.3797
21	24	2.752	0.7792
24	25	3.0272	0.8571
25	26	2.752	0.7792
26	27	2.752	0.7792
6	14	0.9108	0.3797
14	15	1.8216	0.7594
15	16	1.8216	0.7594
16	17	0.9108	0.3797
16	18	1.376	0.3896
18	19	1.376	0.3896

Bus data for 52 bus system

Bus no.	P_L	Q_L
1	0	0
2	81	39
3	135	65
4	108	52
5	108	52
6	27	13
7	54	26
8	135	65
9	81	39
10	67	32
11	27	13
12	27	13
13	108	52
14	54	26
15	94	45
16	67	33
17	67	33
18	108	52

19	81	39
20	108	52
21	94	46
22	81	39
23	108	52
24	108	52
25	102	50
26	41	20
27	108	52
28	162	79
29	68	33
30	68	33
31	95	46
32	41	20
33	121	59
34	41	20
35	41	20
36	135	66
37	81	40
38	68	33
39	95	46
40	108	52
41	41	20
42	95	46
43	27	13
44	122	59
45	108	52
46	81	39
47	68	33
48	41	20
49	68	33
50	81	39
51	108	52
52	41	20

Line data for 52 bus system

From bus	To bus	R	X_L
1	2	0.0258	0.0111
2	3	0.043	0.0185
2	4	0.0129	0.0056
4	5	0.0129	0.0056
4	6	0.0086	0.0037
6	7	0.0172	0.0074
6	8	0.0215	0.0093

8	9	0.0258	0.0111
9	10	0.043	0.0185
10	11	0.0129	0.0056
11	12	0.0086	0.0037
11	15	0.043	0.0185
12	13	0.0301	0.013
12	14	0.0344	0.0148
10	16	0.0129	0.0056
16	17	0.0516	0.0222
16	18	0.043	0.0185
18	19	0.0344	0.0148
1	20	0.0086	0.0037
20	21	0.0129	0.0056
21	22	0.0258	0.0111
22	23	0.043	0.0185
23	24	0.0215	0.0093
22	25	0.0258	0.0111
25	26	0.0344	0.0148
20	27	0.0086	0.0037
27	28	0.0129	0.0056
28	29	0.0215	0.0093
27	30	0.0344	0.0148
30	31	0.043	0.0185
1	32	0.0344	0.0148
32	33	0.043	0.0185
33	34	0.0344	0.0148
33	35	0.0301	0.013
35	36	0.0344	0.0148
36	37	0.0215	0.0093
35	38	0.0172	0.0074
33	39	0.0215	0.0093
39	40	0.0172	0.0074
39	41	0.0215	0.0093
41	42	0.0258	0.0111
41	43	0.0387	0.0167
43	44	0.043	0.0185
41	45	0.0129	0.0056
45	46	0.0301	0.013
45	47	0.0215	0.0093
47	48	0.0129	0.0056
47	49	0.0129	0.0056
49	50	0.0344	0.0148
49	51	0.0129	0.0056
51	52	0.0086	0.0037