M. Tech (Power System) OM PATHAK 2019

OPTIMAL DISTRIBUTED GENERATION PLANNING IN RADIAL DISTRIBUTION SYSTEMS

DISSERTATION/THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
IN
POWER SYSTEMS

Submitted by:

Om Pathak

2k17/PSY/11

Under the supervision of

Mr. PREM PRAKASH
(Assistant Professor)

DEPARTMENT OF ELECTRICAL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

2019

DEPARTMENT OF ELECTRICAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, **Om Pathak**, Roll No. 2K17/PSY/11 student of M.Tech (Power System), hereby declare that the project Dissertation titled **"Optimal Distributed Generation Planning in Radial Distribution Systems"** which is submitted by me to the Department of Electrical Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously submitted for the award of any Degree, Diploma.

Place: Delhi **(Om Pathak)**

Date: 23/07/2019

DEPARTMENT OF ELECTRICAL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I, **Om Pathak**, Roll No. 2k17/PSY/11 student of M. Tech. (Power System), hereby declare that the dissertation/project titled **"Optimal Distributed Generation Planning in Radial Distribution Systems"** under the supervision of Mr. Prem Prakash of Electrical Engineering Department Delhi Technological University in partial fulfillment of the requirement for the award of the degree of Master of Technology has not been submitted elsewhere for the award of any Degree.

Place: Delhi **(OM PATHAK)**
Date: 23.07.2019

(PREM PRAKSH)
ASSISTANT PROFESSOR, EED, DTU

DEPARTMENT OF ELECTRICAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

ACKNOWLEDGEMENT

I would like to express my gratitude towards all the people who have contributed their precious time and effort to help me without whom it would not have been possible for me to understand and complete the project.

I would like to thank Mr. Prem Praksh (Assistant Professor), DTU Delhi, Department of Electrical Engineering, my Project guide, for supporting, motivating and encouraging me throughout the period of this work was carried out. His readiness for consultation at all times, his educative comments, his concern and assistance even with practical things have been invaluable.

Date: 23/07/19

Om Pathak
M.Tech (Power System)
Roll No. 2K17/PSY/11

ABSTRACT

The objective of present dissertation is to minimize losses and at the same time maintain acceptable voltage profiles in a radial distribution system. Distributed generation (DG) is a research oriented topic nowadays because of its enumerable advantages and due to the ever increasing demands for electrical energy. Thus the proposed method optimally size and place DGs in appropriate buses in the system, making the problem such a way reducing real power losses, operating cost and enhancing the voltage stability, which becomes the objective function. Voltage profile improvement is considered as a constraint in finding the optimal placement of DG. Since the problem involves optimization of variables, a new hybrid optimization method integrating two powerful well established techniques is proposed. The prime idea of the proposed technique is to utilize the key features of both techniques to collectively and effectively search for better optimization results. The simulation results shows that reduction of power loss in distribution system is possible and all node voltages variation can be achieved within the required limit if DGs are optimally placed in the system. In modern load growth scenario uncertainty load and generation model shows that reduction of power loss in distribution system is possible and all node voltages variation can be achieved within the required limit without violating the thermal limit of the system.The proposed algorithms are applied and demonstrated on the IEEE 85-bus distribution systems. The results obtained depict the effectiveness of the proposed hybrid GA-PSO algorithm in comparison with those of GA and PSO methods when applied independently.

TABLE OF CONTENTS

CHAPTER-3: INCORPORATION OF DG MODEL IN DISTRIBUTION NETWORK LOAD FLOW

CHAPTER-4: GENETIC ALGORITHM OPTIMIZATION FOR DG

CHAPTER-5: OPTIMAL DG ALLOCATION USING PARTICLE SWARM OPTIMIZATION

CHAPTER-6: OPTIMAL DG ALLOCATION USING HYBRID GA-PSO OPTIMIZATION

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

S No	Abbreviated Name	Full Name
1	DG	Distributed generation
2	IC	Internal Combustion Engines
3	GA	Genetic Algorithm
4	PSO	Particle Swarm Optimization
5	DSs	Distribution Systems
6	RES	Renewable Energy Sources
7	AIS	Artificial Immune System
8	MDNA-GA	Modified Genetic Algorithm
9	DI	Diversity Index
10	RDN	Radial Distribution Networks
11	ECI	Equivalent Current Injections
12	BIBC	Bus Injection to Bus Current Matrix
13	BCBV	Branch Current To Bus Voltage Matrix
14	KCL	Kirchhoff's Current Law
15	KVL	Kirchhoff's Voltage Law
16	VSI	Voltage Stability Index

LIST OF SYMBOLS

S. NO.	SYMBOLS	DESCRIPTION
1	f_1, f_2, f_3	Objective Function for Real Rower Loss, Voltage profile Deviation and VSI
2	F	Combination of Multi Objective Functions
3	w_1, w_2, w_3	Weights Associated to f_1, f_2, f_3
4	$P_{lineloss}$	Active Power Loss
5	$Q_{lineloss}$	Reactive Power Loss
6	V_{min}	Minimum Bus Voltage
7	V_{max}	Maximum Bus Voltage
8	Pd	Real Power Demand
9	Qd	Reactive Power Demand
10	P_{DG}	Active Power supplied by DG
11	Q_{DG}	Reactive Power supplied by DG
12	S	Complex Power
13	I_i	Equivalent Current Injection
14	IB_i	Branch Current
15	IL_i	Load Current
16	ZD	Diagonal Impedance Matrix
17	δ	Voltage Angle
18	θ	Power Factor Angle
19	IL_{PQ}	Load Currents for Constant Complex Power Loads
20	Z	Constant Load Impedance Load
21	IL_Z	Load Current for Constant Load Impedance
22	IL_I	Load Current for Constant Current Load
23	ZP	Percentage of Constant Z-Type Load
24	IP	Percentage of Constant I-Type Load
25	SP	Percentage of Constant PQ-Type Load
26	IL_{ZIP}	Load Current for Composite Load
27	x_i^k	Particle Position
28	v_i^k	Particle Velocity
29	w	Inertia Weight
30	p_i^k	"Remembered" Individual Particle Position
31	p_g^k	Best "Remembered" Swarm Position
32	c_1, c_2	Cognitive and Social Parameters
33	r_1, r_2	Random Numbers Between 0 and1

CHAPTER-1
INTRODUCTION

1.1 Introduction

Loss Minimization in influence networks has expected more noteworthy importance, in light of the way that tremendous measure of produced influence is constantly wasted as losses. Studies have exhibited that nearly 70% of the total networks losses are going on in the distribution systems, while transmission system speak to only 30% of the total losses [1]. The weight of improving the general capability of intensity conveyance has constrained the power utilities to decrease the loss, especially at the distribution level. The accompanying methodologies are grasped for decrease of distribution system losses [1-2].

- Feeder reinforcement.
- Reactive power settlement.
- High voltage distribution networks.
- Conductor grading.
- Feeder reconfiguration.
- Placement of Distributed Generator.

Smart grid idea is required to turn into an upcoming power network [6]. In accomplishing a Smart Grid idea, countless distributed generators (DG) are required inside distribution network which is founded to fill up to 40-45% of the distribution system's load request. This generous numbers of DGs are obliged to participate in upgrading the security, unwavering quality and nature of power supply by giving dynamic power and other subordinate administrations, for example, controlling the voltage by giving their reactive power supply to the network. One of the qualities of future power network under brilliant framework thought is to have an effective transmission and distribution network that will decrease line losses [3]. Limiting line losses inside influence transport networks will being about simpler use of petroleum derivative thus decreased spread of air toxin and nursery gasses. Organizing of DG inside distribution network decreases control misfortunes in light of the way that some part of the required load current from upstream is liberally diminish which result lower misfortunes through line opposition. Further decrease of losses can be achieved by wisely overseeing responsive influence from presented DG [6].

Table 2.1: DG classification on the basis of size [4]

S. NO.	CLASS	SIZE
1	Micro distributed generation	1 W≤ 5kW
2	Small distributed generation	5 kW≤ 5 MW
3	Medium distributed generation	5 MW ≤ 50 MW
4	Large distributed generation	50 MW ≤ 3000 MW

1.2 Distribution Network Power Loss

An active power loss in the line relies upon size of the present flows through the line and obstruction of the line. In air conditioning distribution circuit, because of electric and attractive field produce by the flow of time shifting flow, inductance and capacitance may be critical. Right when current flow through these two segments, reactive power which transmit no vitality is created. Reactive current flow in the line adds to additional power losses notwithstanding dynamic influence losses notice already. Reconciliation of DG officially decreased dynamic power losses since some part of influence from upstream is now diminished. Loss reduction can be additionally diminished by controlling the voltage profiles in the network. In ordinary practice, capacitor banks are included the distribution network to control the flow of this reactive power. These capacitor banks can be changed in and out utilizing voltage managing hand-off to convey receptive power in steps yet it brought control quality conveyed down to the client as it prompts step changes in bus bar voltage.

1.3 DISTRIBUTED GENERATION:

1.3.1 DG Operational and Planning Issues:

Distributed Generators (DGs) are defined as "electric power sources joined specifically to the distribution system or on the client side of the meter" [3]. This definition generally obliges an assortment of advancements and execution across over differing utility structures, while sidestepping the entanglements of using progressively stringent criteria centered around guidelines, for instance, control appraisals and power conveyance territory. Distribution arranging incorporates the examination of future power conveyance needs and choices, with a goal of making an exact game-plan of increments to the networks required to accomplish pleasant degrees of administration at least by and large expense. Executing DGs in the distribution framework has various benefits, yet meanwhile it goes up against various confinements and restrictions. DG units, being versatile, could be worked to address quick issues and later be scaled upwards in ability to deal with future interest development. Adaptability grants DG units to diminish their capital and activities costs and in this manner significant capital isn't tied up in ventures or in their help framework. Venture assets can moreover be practiced since framework refreshes, (for instance, feeder limit expansions) may be conceded or by and large disposed of. From a customer point of view, assets might be accumulated from the additional choice and adaptability that DGs grant regarding vitality buys [3][5][6]. Then again, on the other hand, introducing DG in the distribution systems can likewise build the unpredictability of networks arranging. DG must be palatably presented and encouraged with the current defensive gadgets and plans. Greater entrance levels of DG can cause regular power flows to adjust (switch course), since with age from DG units, power might be infused anytime on the busbar. New arranging frameworks must ensure that feeders can suit changes in load arrangement. Such impediments and issues must be settled prior to pick DG as an arranging elective. A portion of the related agenda in distribution systems with entrance of DG utilities are as examined straightaway.

1.3.2 Operation of DG:

There are various segments impacting DG activity, for instance, DG advances, types, operational modes, and others. DGs introduced in the distribution system can be possessed, worked and constrained by either an electric unit or a client. If DG is utility-guaranteed, at that point its operating cycle is notable as is constrained by the unit. The condition of the DG operating cycle depends on the inspiration driving its usage in the distribution framework [3][5][6]. For instance:

1.) Peak crest load shaving units with limited working schedule as IC engines and fuel cells.
2.) Limited time operational units to impart load diversifying operating cycles as fuel cell and micro turbines.
3.) Power supply for base load demand as large fuel cells and micro turbines.
4.) Renewable power sources units as wind generators and solar cells.

1.3.3 Optimal location of DG:

There are no pleasing impediments on area of DG units in the distribution framework, as there are no geographical constraints as by virtue of substations. Hence, the fundamental impediments rise up out of electrical necessities. If the DG is customer had then the utility has no control on its area in light of the way that it is put at the customer's site. If the DG is utility-had then the selection of its area is engaged around a couple of electrical elements, for instance:

• Providing the necessary extra load

• Reducing line losses

• Improving system voltage profile and expanding substations capacities to supply more load demand.

Moreover, DG units should be precisely put on networks that do not influence the current defensive protections and ratings.

1.3.4 Sizing of DG

There are no unmistakable rules on choosing the ratings and optimum number of DG utilities to be presented in the system. Be that as it may, a couple of viewpoints can be directing the decision of DG unit measure determination:

a) To improve the networks voltage profile and decrease control losses, it is adequate to use DG units of total limit in the compass of 10-20% of the total feeder demand [3]. While more DG limit could be used to lessen the substation loading [3][5][6].

b) For unwavering quality purposes if there ought to emerge an event of islanding, the DG size must be more noteworthy than twofold the required island load. The DG unit size can influence networks insurance coordination plans and gadgets as it influences the estimation of the short out current during flaw. Henceforth, as the DG size builds, the insurance gadgets, wires, re-closers and transfers settings must be corrected or potentially redesigned [1-2].

1.4) DG Modeling:

There are a few distinct sorts of assets and advancements that can be utilized for DG, for example, wind, sun oriented, energy components, hydrogen and biomass. The load flow models of DGs shift with kinds of DGs . DGs are commonly sorted as :

1.) UPF DG :

Specific kinds of DGs will create genuine power as it were. For instance, photovoltaic frameworks convert sun based vitality into power giving DC power yield.

2.) Capacitor DG

For capacitor DG, for example, synchronous compensator, it gives just reactive power capacity to improve system conditions.

3.) Wind turbine DG

Here we think about that the DG will provide active power and thus will retain reactiv power. In the event of the breeze turbines, acceptance generator is utilized to create active power and the reactive power gets expended all the while.

4.) Synchronous DG

With the utilization of interfacing power electronics hardware, DGs like fuel cell, current controlled photovoltaic produces both active and reactive power. Synchronous generator is likewise used to create active and reactive power.

5.) Micro turbine DG

If there should arise an occurrence of miniaturized scale turbine DGs, the voltage at the transport to which DG is associated will dependably be fixed. Active power infused by the DG will be found and required reactive capacity to help the transport voltage will be given by means of intensity electronic interface gadgets.

1.5) Problem Formulation

The issue of ideal position and measuring of DG is planned as optimization issue. To detail the issue it is important to characterize the objective function to be upgraded along with fulfilling the working requirements. Contingent on the quantity of objectives to be accomplished all the while, the improvement issue can display in one of the two structures in particular single objective enhancement issue and multi-objective streamlining issue. In this section, for a multi-objective optimization issue, arrangement goes for limiting system active power loss, improving voltage profile and voltage stability.

For multi-objective function

$$F = w_1 f_1 + w_2 f_2 + w_3 f_3 \tag{1.1}$$

Where w_1, w_2, w_3 are the loads that choose the relating significance to every one of the goal work.

And $$|w_1| + |w_2| + |w_3| = 1 \tag{1.2}$$

1.6) Objective Function

Prime objective of this enhancement issue is to decide the best areas and rating of the DGs which will streamline different tasks identified with framework execution. As expressed before for multi objective streamlining issue, objective function is not to be limited to framework power loss. For multi-objective streamlining issue, three goals f_1, f_2, f_3 are studied. These goals are minimization of network power loss, enhancement in voltage profile and stability as far as possible separately. A solitary objective function is shaped which is a direct function of these three aims. Every one of the stated goals is clarified beneath.

System Real power loss

$$f_1 = \frac{\sum_{i=1}^{L} \left(P_{lineloss}(i)\right)_{afterDG}}{\sum_{i=1}^{L} \left(P_{linelosss}(i)\right)_{beforeDG}} \tag{1.4}$$

Voltage Profile Deviation

The objective function to enhance voltage profile can be depicted as

$$f_2 = \frac{\sum_{i=1}^{N} \left|V_i - V_{iref}\right|_{afterDG}}{\sum_{i=1}^{N} \left|V_i - V_{iref}\right|_{beforeDG}} \tag{1.5}$$

Voltage Stability Index (VSI):

VSI can be describe as

$$VSI(k) = |V_i|^4 - 4(P_k.X_{ik} - Q_k.R_{ik})^2 - 4(P_k.R_k + Q_k.X_k).|V_i|^2 \tag{1.6}$$

Thus objective function associated with VSI is defined as follows-

$$f_3 = \frac{1}{VSI(k)_{afterDG}} \tag{1.7}$$

Minimization of this objective function can be reflected as maximization of VSI.

Thus the combination of the stated goals as a multi-objective function is

$$F = \min\left(w_1 f_1 + w_2 f_2 + w_3 f_3\right) \tag{1.8}$$

Since the three function esteems have various units, every one of them is standardized by particular base case esteem. In the articulation for multi-objective function, are the penalty or significance circumstances that choose the relating significance to every objective function. All in all it is hard to decide reasonable estimations of the importance factors. In this way the experience of the distribution specialists and heuristics ought to be wisely utilized so as to get sufficient qualities. Besides the significance components ought to be adaptable since electric units present various worries with reference to system loss, voltage deviation and stability.

1.7 Constraints

Constraints enforced in this optimization problem are

1. Real and imaginary power balance limits
2. Voltage limits
3. DG limits

Real and imaginary power balancing constraint:

Real and imaginary power balance equations at the j^{th} bus are represented as follows:

$$P_{swing} + \sum_{i=1}^{N} P_{DG}(i) = \sum_{i=1}^{L} P_{lineloss}(i) + \sum_{q=1}^{N} Pd\ (q) \tag{1.9}$$

$$Q_{swing} + \sum_{i=1}^{N} Q_{DG}(i) = \sum_{i=1}^{L} Q_{lineloss}(i) + \sum_{q=1}^{N} Qd\ (q) \tag{1.10}$$

Voltage Limits

To guarantee that voltage of each transport in the framework ought to be inside predefined limits the accompanying limitation is considered:

$$V_{\min} \le |V_i| \le V_{\max} \tag{1.11}$$

Where V_i = $i\ t$h bus voltage

V_{min} = minimum bus voltage

V_{max} = maximum bus voltage

System's voltage limits are considered to be ± 6 % of the nominal voltage value.

DG size limits

To have a considerable impact of DG on system and to avoid voltage rise problem, limits are enforced on DG ratings.

Active power generation by DG is bounded as

$$P_{DG}^{\min} \leq P_{DG}(i) \leq P_{DG}^{\max} \tag{1.12}$$

DG at any transport is accepted to create the dynamic power inside cutoff points given above.

And reactive power generation by DG is bounded within following limits

$$Q_{DG}^{\min} \leq Q_{DG}(i) \leq Q_{DG}^{\max} \tag{1.13}$$

1.8 SUMMARY

In this part the discussion is about the important issues and goes for giving a general definition to appropriated DG in focused power markets. The brief introduction for the DG objective function and its constraints has been discussed. The basic idea of the DG installation is to reduce the voltage sag or swell, power loss reduction and stability enhancement. The objective function is used in various algorithms in the work. The load flow is analysis has been done prior to allocate DG in the system.

CHAPTER-2

LITERATURE REVIEW

1.1 INTRODUCTION

The cutting edge distribution system is always being looked with a regularly developing burden request, this expanding burden is coming about into expanded weight and decreased voltage [1]. The dissemination arrange likewise has a run of the mill include that the voltage at (nodes) decreases whenever moved far from substation. The advanced power system is always being subjected to a consistently developing burden request, this expanding burden is coming about into expanded power demand and low voltage. This reduction in voltage is primarily because of deficient measure of reactive power. Indeed, even in certain industry, it might prompt voltage collapse due to critical loading. In this way to improve the voltage profile and to stay away from voltage breakdown responsive pay is required [1-2]. The low X/R ratio leads to higher power loss and voltage sag when compared with transmission lines [1-3].Such non-unimportant misfortunes directly affect the monetary issues and generally performance of distribution system. The importance of enhancing the performance has constrained the power utilities to lessen the losses at distribution level. Numerous courses of action can be applied to diminish these misfortunes like system reconfiguration, shunt capacitor, distributed generation placement etc [1-3]. The distributed generators supply some portion of dynamic power request, in this manner lessening the current and MVA in lines. Establishment of DGs on power system will contribute in lessening vitality misfortunes, top interest misfortunes and enhancement in the systems voltage profile, systems steadiness and influence factor of the systems [3, 4]. Distributed generation (DG) innovations under smart grid idea frames the foundation of our reality Electric appropriation systems [4] [6]. These DG advances are grouped into two classes: (I) sustainable power sources (RES) and (ii) petroleum derivative based sources. Sustainable power sources (RES) based DGs are biomass, wind turbines, photovoltaic, , geothermal, little hydro, and so on. Non-renewable energy source based DGs are the internal combustion engines (IC), combustion turbines and fuel cells [3] [5].

Nearness of distributed generation in dissemination systems is a pivotal test regarding specialized and well being issues [7-9]. In this way, it is basic to assess the specialized effects of DG in power systems. Hence, the generators are should have been associated in conveyed frameworks in such a way, that it maintains a strategic distance from debasement of intensity quality and unwavering quality. Assessment of the specialized effects of DG in the power systems is basic and arduous. Deficient allotment of DG as far as its area and limit may prompt increment in shortcoming flows, causes voltage varieties, meddle in voltage-control forms, lessen or increment misfortunes, increment framework capital and working expenses, and so forth [8]. Also, introducing DG units isn't clear, and hence the arrangement and measuring of DG units ought to be painstakingly tended to [8-9].

Examining this improvement issue is the significant inspiration of the present postulation look into. DG portion is fundamentally a typical combinatorial enhancement agenda which needs simultaneous improvement of numerous destinations [10], for example minimizations of active and reactive power losses, bus voltage deviation, carbon radiation, line stacking, and impede and augmentation of system unwavering quality and so forth. The objective is to decide the ideal location(s) and size(s) of DG units in distribution system. The enhancement is completed under the limitations of most extreme DG ratings, warm breaking point of system branches, and voltage farthest point of the nodes [9-10]. In [11], an explanatory way to deal with the ideal area of DG is exhibited. In the vast majority of the present works, populace based developmental calculations are utilized as arrangement techniques. This incorporates hereditary calculation (GA) and molecule swarm enhancement [6] [13-16] and so on. The benefits of populace based meta-heuristics calculations, for example, GA and PSO are that a lot of non-overwhelmed arrangements can be found in a solitary run due to their multi-point search limit. They are additionally less inclined to dimensionality issues; nonetheless, intermingling isn't constantly ensured.

2.2 OBJECTIVE OF THE WORK

A creative proposition for DG optimal location and sizing to approach consolidating improvement calculation for a group of DG units is presented in this work. An ongoing load flow technique BFS (i.e. backward/forward sweep) method for a radial distribution system utilizing BIBC and BCBV lattice has been utilized. The target capacities planned in this work are minimization of system line loss and node voltage deviation. In this study IEEE 85 bus system is used to analyze the Genetic Algorithm, Particle swarm optimization and hybrid GA-PSO algorithms for different types of DGs like capacitor DG, unity power factor DG and Synchronous DG and comparison among the algorithms has presented for various DG types.

2.3 Distribution Networks and Distributed Generation

The advanced power dispersion system is always being looked with an exceptionally quick developing burden request, this expanding burden is coming about into expanded weight and decreased voltage likewise impact on the activity, arranging, specialized and security issues of appropriation systems [6]. This power misfortune in conveyance systems have turned into the most concerned issue in influence misfortunes investigation in any influence systems. In the exertion of lessening power misfortunes inside conveyance systems, receptive influence remuneration has turned out to be progressively significant as it influences the operational efficient and nature of administration for electric influence systems [6]. The arranging ought to be with the end goal that the structured framework ought to financially and dependably deal with spatial and worldly burden development, and administration territory extension in the arranging skyline [7-8]. In [7], different dissemination systems arranging models exhibited. The proposed models are gathered in a three-level arrangement structure beginning with two general classifications, i.e., arranging without and with unwavering quality contemplations. Arranging of a circulation framework depends on upon the heap stream consider. The heap stream will be basic for the examination of circulation systems, to inquire about the issues related to arranging, diagram and the task and control. Therefore, the heap stream consequence of dispersion systems should have ronodet and time capable characteristics.

The heap stream for appropriation framework isn't similar transmission framework because of some in conceived qualities of its own. There are not many methods are accessible in writing. Ghosh and Das [18] proposed a strategy for the heap stream of outspread dissemination system utilizing the assessment dependent on arithmetical articulation of accepting end voltage. Teng et al. [19] has proposed the heap stream of spiral dispersion systems utilizing hub infusion to branch-current (BIBC) and branch-current to hub voltage (BCBV) lattices. With the deregulation of vitality markets, raising expenses of petroleum derivatives, and socio ecological weights, control systems organizers are beginning to get some distance from the incorporated power systems topology by introducing littler, sustainable fueled generators at the conveyance level [3, 4] which is known as circulated age. These DG innovations are grouped into two classifications: (I) sustainable power sources (RES) and (ii) petroleum derivative based sources. Sustainable power source (RES) based DGs are wind turbines, photovoltaic, biomass, geothermal, little hydro, and so forth. Petroleum product based DGs are the inner ignition motors (IC), burning turbines and energy units [3] [5. The advancements behind these inexhaustible controlled generators are developing to make these generators greater utility-accommodating (and hence increasingly prudent). A portion of the DG innovations contend with ordinary concentrated age advancements in operational angles and cost. DG assignment in conveyance framework is fundamentally a complex combinatorial streamlining issue which requires simultaneous improvement of numerous goals [10], for example minimizations of genuine and responsive power misfortunes, hub voltage deviation, carbon spread, line stacking, and cut off and expansion of system unwavering quality and so on. By and by, an enormous number of research papers are accessible regarding the matter of the DG assignment for power misfortune, voltage improvement, and so on [4-6]. Kashem et al. [17] introduced an affectability lists to show the adjustments in power misfortunes regarding DG current infusion. I Erlich et al. [6] present another plan approach for overseeing receptive power from a gathering of circulated generators set on a spiral dissemination systems.

An ever increasing number of DGs are presently being coordinated into the circulation systems which have influenced the activity, arranging, specialized and wellbeing issues of dissemination systems [6-9]. Assessment of the specialized effects of DG in the power systems is basic and arduous. Insufficient distribution of DG as far as its area and limit may prompt increment in issue flows, causes voltage varieties, meddle in voltage-control forms, reduce or increment misfortunes, increment framework capital and working expenses, and so on [8]. In addition, introducing DG units isn't direct, and along these lines the arrangement and measuring of DG units ought to be deliberately tended to [8-9].

Improvement is a procedure by which we attempt to discover the best arrangement from set of accessible option. In DG allotment issue, DG areas and sizes must be enhance so that it give most conservative, effective, in fact sound circulation framework. By and large dissemination framework have numerous hubs and it is exceptionally elusive out the ideal DG area and size by hand. There are various streamlining systems utilized in the writing. Among the distinctive arrangement systems deterministic calculation, for example, dynamic programming, blended whole number programming, nonlinear programming and Benders deteriorating have been utilized. In [11], an expository way to deal to decide the ideal area of DG is displayed. The focal points of populace based meta-heuristics calculations, for example, GA and PSO are that a lot of non-commanded arrangements can be found in a solitary run on account of their multi-point search limit. They are likewise less inclined to dimensionality issues; in any case, assembly isn't constantly ensured. Hereditary Algorithms offer a 'one size fits all' answer for critical thinking including search [20]. In contrast to other customary hunt choices, GA's can be connected to most issues, just requiring a decent capacity determination to streamline and a decent decision of portrayal and translation. This, combined with the exponentially expanding rate/cost proportion of PCs, settles on them a decision to consider for any hunt issue. Genetic Algorithms (GAs) are flexible exploratory chase procedures centered around the transformative thoughts of trademark decision and hereditary qualities. A hereditary calculation is a heuristically guided arbitrary inquiry procedure that simultaneously assesses a great many proposed arrangements. One-sided irregular determination and blending of the assessed inquiries is then completed so as to advance towards better arrangements. The coding and control of inquiry information depends on the task of hereditary DNA and the choice procedure is gotten from Darwin's survival of the fittest'. Search information are normally coded as twofold strings called chromosomes, which by and large structure populaces [20]. Assessment is completed over the entire populace and includes the use of, frequently complex 'wellness' capacities to the series of (qualities) inside every chromosome. Normally, blending includes recombining the information that are held in two chromosomes that are chosen from the entire populace.

The conventional hybrid like incompletely coordinated hybrid, request hybrid and cycle hybrid, and so forth and transformation would make some unfeasible answer for be made. In the customary hybrid and change, hybrid likelihood and transformation likelihood are not versatile in nature and which have no adaptability. Thus when a fundamental GA improvement procedure caught in a neighborhood minima these hybrid and transformation likelihood can't rise up out of the nearby minima and GA enhancement give an untimely outcome.

2.4 ORGANIZATION OF THE REPORT

The work did in this Report have been abridged in seven sections. In the chapter 1 brief introduction of DGs, types of DG, problem formulation for the objective function for siting and sizing of DGs are discussed. The chapter 2 depicts the various literatures by the researchers in recent time for the load flow and DG, objective of the work and the organization of the report. Chapter 3 describes the incorporation of DG in load flow and various load models and their load flow results with comparison among them by using BIBC and BCBV matrices (i.e. Backward Forward Sweep Load Flow Method). The chapter 4 illustrates Genetic Algorithm, GA parameters and procedure for siting and sizing of DG using Genetic Algorithm. The Chapter 5 details the Particle Swarm Optimization, PSO parameters and steps for DG allocation using Particle Swarm Optimization. The Chapter 6 briefly describes the hybrid GA-PSO technique and steps for optimal siting and sizing of DG using hybrid GA-PSO algorithm. The Chapter 7 highlights the comparison among the various algorithms for different type of DGs.

CHAPTER-3

DG MODEL INCORPORATION IN DISTRIBUTION NETWORK LOAD FLOWS

3.1 INTRODUCTION

The load flow is the primary work in power system before planning or expansion which provides the various parameters of the network as voltage sag or swell, maximum or minimum current through any branch, power loss etcThe load flow will be basic for the examination of circulation systems, to inquire about the issues related to arranging, diagram and the activity and control. A couple of arrangements like perfect conveyed age situation in dissemination systems and appropriation robotization systems, obliges repeated load flow result. Various frameworks such Gauss-Seidel, Newton-Raphson are for the most part showed up for pass on the load flow of transmission systems [1]. The use of these frameworks for appropriation systems may not be beneficial in light of the way that they will be commonly engaged around the general coincided topology of a typical transmission systems albeit most conveyance systems structure are likely in tree, radial or weakly mesh in nature. R/X proportion of appropriation systems is high regard to transmission framework, which cause the distribution systems to be seriously shaped for customary load flow procedures.

The viability of the enhancement issue of distribution networks depends on upon the load flow calculation in light of the fact that load flow result need to keep running for commonly. Subsequently, the load flow consequence of distribution networks should have ronodet and time capable characteristics. A strategy which can find the load flow consequence of spiral distribution networks explicitly by using topological typical for distribution framework is used. In this procedure, the arrangement of repetitive Jacobian grid or admittance matrix, which are required in standard methods, is avoided.

3.2 Equivalent Current Injection :

The technique is based on the equivalent current injection of a node in distribution networks, the equivalent-current-injection model is more practical. For any node of distribution networks, the complex load S_i is expressed by

$$S_i = P_i + jQ_i \qquad i = 1,2,..........N_B \tag{3.4}$$

Now, the equivalent current injection is expressed as

$$I_i = I_i^r(V_i) + jI_i^i(V_i) = \left(\frac{P_i + jQ_i}{V_i}\right)^* \tag{3.5}$$

For the load flow solution equivalent current injection (ECI) at the k-th iteration at i-th node is computed as

$$I_i^k = I_i^r(V_i^k) + jI_i^i(V_i^k) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^* \tag{3.6}$$

3.2 Formation of BIBC and BCBV Matrix

It explains a direct correlation of the node current injection with branch current. The power injections at each node can be transformed into the equivalent current injection. The relation of node current with branch current can be easily obtain by using KCL (Kirchhoff's current law) with backward sweep. Now each the branch current can be shaped as a function of the equivalent current injection (ECI) [9].For example, in fig. 1, branch currents IB1, IB2 and IB3 can be expressed by ECI [69- 70] [73].

$$IB1 = IL2 + IL3 + IL4 + IL5 + IL6$$
$$IB2 = IL3 + IL5$$
$$IB3 = IL4 + IL6$$

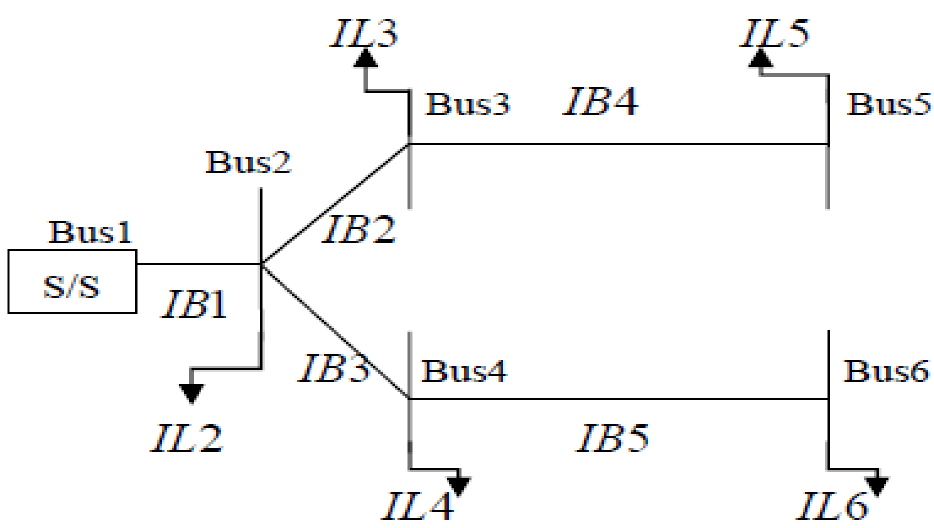

Figure 3.1. Simple distribution system

$$\begin{bmatrix} IB1 \\ IB2 \\ IB3 \\ IB4 \\ IB5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} IL2 \\ IL3 \\ IL4 \\ IL5 \\ IL6 \end{bmatrix}$$

$$[IB_i] = [BIBC][IL_{i+1}] \tag{3.7}$$

BCBV MATRIX:

It builds a direct correlation of branch current with node voltage. This relation can be achieved easily by applying KVL (Kirchhoff's voltage law) with forward sweep. It can be calculated using $[BIBC]$and diagonal impedance matrix $[ZD]$as given

$$[BCBV] = [BIBC]^T [ZD] \tag{3.8}$$

3.3 LOAD MODELING

Loads modeling developed is to be used in the process of iteration of a power flow program where the initial values of node voltage are assumed. Load on a feeder can be modeled as wye-connected or delta connected. The modeling of load can be done as :

- Constant complex power(constant PQ)
- Constant current (constant I)
- Constant impedance (constant Z)
- Composite (ZIP)

All models are at first characterized by a complex power per phase and an assumed line to neutral voltage (wye load) or an assumed line to line voltage(delta load).

The notation for the complex powers and voltage are as:

$$S = P + j * Q = |S| \angle \theta \tag{3.9}$$

$$V = |V| \angle \delta \tag{3.10}$$

i) CONSTANT PQ LOADS :-

The line currents for constant complex power loads are given by

$$IL_{PQ} = \left[\frac{|S|}{|V|} \right] \angle(\delta - \theta) \tag{3.11}$$

In this modeling, the value of load voltage will change during each iteration to achieve convergence.

ii) CONSTANT IMPEDANCE (Z)LOADS :-

In this model, the constant load impedance is determined first. The calculation is based upon the complex power and assumed voltages, given as

$$Z = \left[\frac{|V|^2}{|S|} \right] \angle \theta \tag{3.12}$$

Load currents as a function of the constant load impedance are given by

$$IL_Z = \left[\frac{|V|}{|Z|} \right] \angle(\delta - \theta) \tag{3.13}$$

iii) CONSTANT CURRENT LOADS:-

In this modeling the magnitudes of the currents are calculated according to Equation (1) and are then held constant while the angle of the voltage (delta) changes, resulting in a changing angle of the current such that the load power factor remains constant.

$$IL_I = (S/V)^* = \left[\frac{|S|}{|V|} \right] \angle(\delta - \theta) \tag{3.14}$$

Where δ = voltage angle

θ = power factor angle

iv) COMPOSITE LOAD (ZIP LOADS):-

ZIP loads are demonstrated by doling out a level of the aggregate load to the three above load models. The total line current entering the load is the addition of the three load current components. The values of ZIP coefficients can be changed according to system specification.

ZIP COEFFICIENTS:-

- ZP = percentage of constant Z-type load
- IP = percentage of constant I-type load
- SP = percentage of constant PQ-type loads

Here we have taken, ZP=0.30, IP=0.10, SP=0.60

As $ZP+IP+SP=1$

$$IL_{ZIP} = I_Z + I_I + I_{PQ} \qquad (3.15)$$

Thus $I_Z = ZP * IL_Z$

$$I_I = IP * IL_I$$
$$I_{PQ} = SP * IL_{PQ}$$

3.4 ALGORITHMFOR LOAD FLOW OF DISTRIBUTION NETWORKS:

- Step-I: Read the input line and bus data.
- Step-II: Determine the each node current or node current injection matrix using (7), (8) (11), (13), (14), and (15).
- Step-III: Calculate BIBC matrix as shown in section 3.2.2.
- Step-IV: Calculate the $[BCBV]$ matrix using $[BIBC]$ and diagonal impedance matrix $[ZD]$

  $$[BCBV] = [BIBC]^T [ZD]$$

- Step-V: Calculate $[DLF]$ with simple multiplication of $[BCBV]$ and $[BIBC]$

  $[DLF] = [BCBV][BIBC]$

- Step-VI: Evaluate the branch currents by using $[BIBC]$ matrix and equivalent current injections for their respective load models,

  $[IB] = [BIBC][IL]$

  $[\nabla V] = [DLF][IL]$

- Step-VII: Set iteration, $K = 0$
- Step-VIII: Iteration, $K = K + 1$

- Step-IX: Update voltage by using specified load models

  $[\nabla V^{K+1}] = [DLF][IL^{K}]$

  $[V^{K+1}] = [V^{0}] + [\nabla V^{K+1}]$

- Step-X: If max $[|V(K+1)| - |V(K)|]$ > tolerance, go to step VIII for next iteration.

- Step-XI: Calculate branch currents and losses from final node voltage.

- Step-XII: Display the magnitudes of node voltage and losses.

- Step-XIII: Stop.

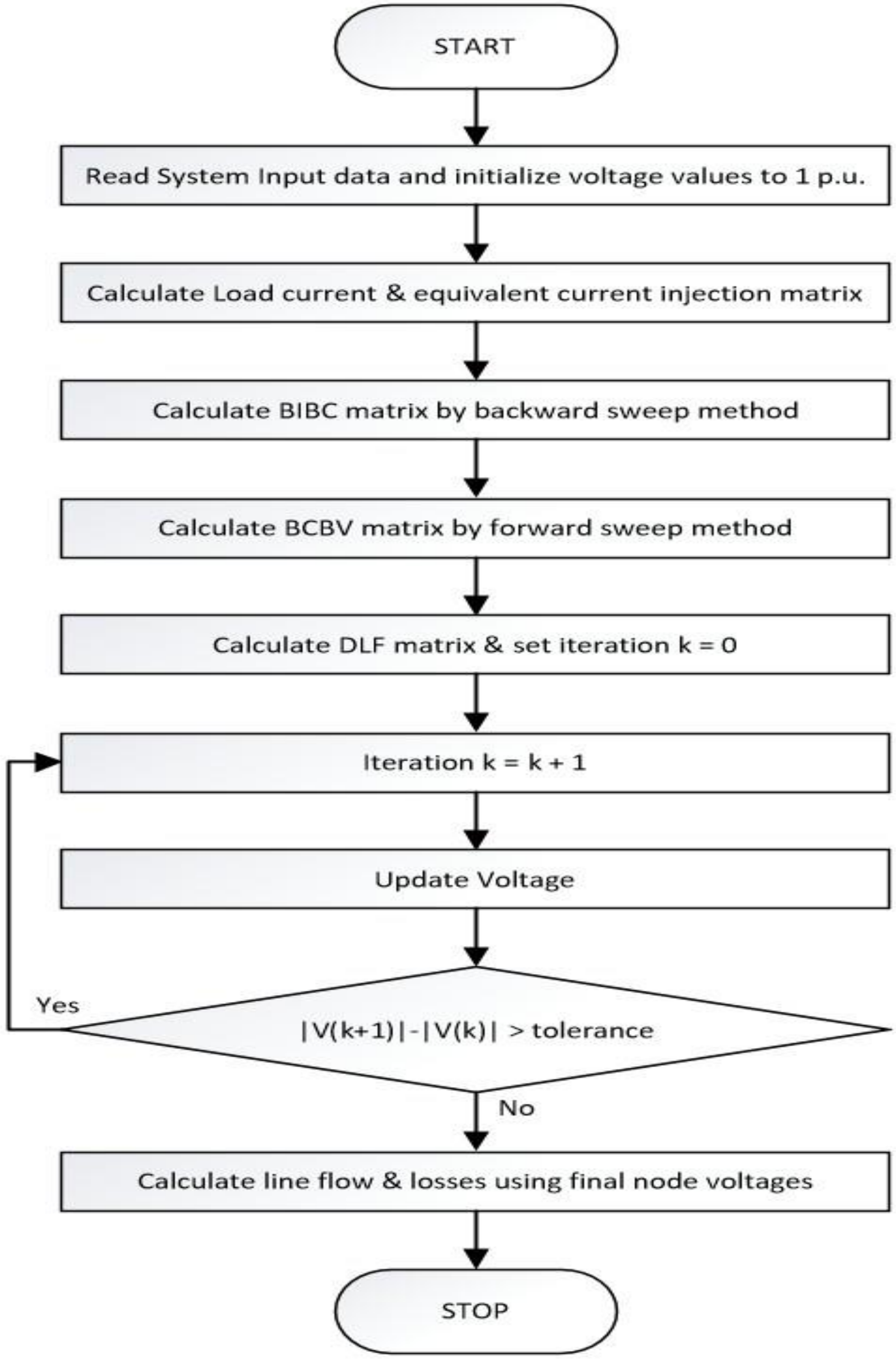

FIGURE 3.1 FLOWCHART FOR LOAD FLOW SOLUTION FOR RADIAL DISTRIBUTION NETWORKS.

3.5 DG INCORPORATION INTO LOAD FLOW

Expect that a single source radial distribution systems with N branches and a DG is to be set at node I and α be a lot of branches associated between node I and the source. It is realized that, the DG supplies active power to the frameworks, however if there should arise an occurrence of reactive power it is rely on the wellspring of DG, it is possible that it is supplies to the frameworks or devour from the frameworks. Because of this dynamic and receptive power a functioning present and responsive current flows through the framework, and it changes the dynamic and responsive segment of current of branch set α. The current of different branches are unaffected by DG.

Apparent Power at i^{th} node :

$$S = S_{D\_i} = \sum P_{D\_i} + jQ_{D\_i} \qquad i = 1,2....N_B \tag{3.16}$$

Current at i^{th} node:

$$I_D = I_{D\_i}^{wiithout\_DG} = \left(\frac{S_{D\_i}}{V_i}\right)^* \tag{3.17}$$

The active and reactive power demand at some node i after incorporation of DG model can be given as :

$$P_{D\_i}^{with\_DG} = P_{D\_i}^{without\_DG} - P_{G\_i}^{DG} \tag{3.18}$$

$$Q_{D\_i}^{with\_DG} = Q_{D\_i}^{without\_DG} \mp Q_{G\_i}^{DG} \tag{3.19}$$

DG power at i^{th} node:

$$S_{DG\_i} = \sum P_{G\_i}^{DG} \pm jQ_{G\_i}^{DG} \tag{3.20}$$

So ,modified current at i^{th} node:

$$I_D = I_{D\_i}^{with\_DG} = \left(\frac{S_{D\_i} - S_{DG\_i}}{V}\right)^* \tag{3.21}$$

Thus the modified system power can be described in matrix form as

$$[S] = [S_{Di}] - [S_{DGi}] \tag{3.22}$$

3.5 ALGORITHM FOR DISTRIBUTION SYSTEMS LOAD FLOW WITH DG:

Step 1: Read the input line and bus data.

Step 2: Determine DG power based upon DG modeling and modify the system input data

Step 3: Evaluate the total power demand with DG (i.e. active and reactive power). The relationship can be depicted as-

$$[S] = [S_{Di}] - [S_{DGi}]$$

Step 4: Calculate the load current or node current injection matrix for each node. The relationship can be declared as-

$$[I] = \left[\frac{S}{V}\right]^* = \left[\frac{P - jQ}{V^*}\right]$$

Step 5: Calculate BIBC matrix as shown.

Step 6: Calculate the $[BCBV]$ matrix using $[BIBC]$ and diagonal impedance matrix $[ZD]$

$$[BCBV] = [BIBC]^T [ZD]$$

Step 7: Calculate $[DLF]$ with simple multiplication of $[BCBV]$ and $[BIBC]$

$$[DLF] = [BCBV][BIBC]$$

Step 8: Evaluate the branch currents by using $[BIBC]$ matrix and equivalent current injections for their respective load models,

$$[IB] = [BIBC][IL]$$
$$[\nabla V] = [DLF][IL]$$

Step 9: Set iteration, $K = 0$

Step 10: Update voltages by using equations (),(),() as-

$$I_i^k = I_i^r\left(V_i^k\right) + jI_i^i\left(V_i^k\right) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^*$$

$$\left[\Delta V^{k+1}\right] = [DLF].\left[I^k\right]$$

$$\left[V^{k+1}\right] = \left[V^0\right] + \left[\Delta V^{k+1}\right]$$

Step 11: If max $\left(\left(|V(k+1)| - |V(k)|\right) > tolerence\right)$ go to step 6.

Step 12: Calculate branch currents, and losses from final node voltages.

Step 13: Display the node voltage magnitudes and angle, branch currents and losses.

Step 14: Stop.

3.7 LOAD FLOW SOLUTION FOR BASE CASE

Standard IEEE 85 bus system has a single source or substation system with base voltage magnitude of 1 per unit and all other nodes are load node. The system is considered on base MVA and base kV are 100MVA and 12.66 kV respectively with one slack node.

Table 3.1: CONSTANT POWER MODEL LOAD FLOW RESULT

Node/ Branch	***Voltage***	***Angle***	***Current***
1	1	0	0.04012
2	0.996763	0.03442	0.03961
3	0.991962	0.08733	0.03800
4	0.985832	0.15569	0.03719
5	0.98285	0.18943	0.03319
6	0.972131	0.31242	0.03268
7	0.965541	0.38976	0.03215
8	0.937002	0.73601	0.01737
9	0.935621	0.75606	0.00665
10	0.932752	0.81157	0.00579
11	0.930489	0.85814	0.00494
12	0.928573	0.90071	0.00163
13	0.92785	0.90950	0.00108
14	0.92763	0.91218	0.00054
15	0.927499	0.91379	0.00050
16	0.996535	0.04002	0.00161
17	0.991505	0.09853	0.00399
18	0.980814	0.23986	0.00317
19	0.979555	0.27114	0.00154
20	0.979118	0.28200	0.00103
21	0.978593	0.29505	0.00051
22	0.978097	0.30740	0.00081
23	0.979463	0.27345	0.00052
24	0.965246	0.39721	0.01426
25	0.932915	0.83368	0.01372
26	0.929772	0.90930	0.01200
27	0.925645	1.00841	0.01114
28	0.92373	1.05441	0.01027
29	0.920194	1.13917	0.00941
30	0.916955	1.21670	0.00886
31	0.915429	1.25318	0.00831
32	0.914476	1.27598	0.00665
33	0.913709	1.29381	0.00643
34	0.910366	1.37095	0.00425
35	0.908635	1.40813	0.00055
36	0.908572	1.40982	0.00086
37	0.929577	0.91440	0.00086
38	0.925106	1.02258	0.00087
39	0.919899	1.14700	0.00165
40	0.914007	1.28844	0.00110
41	0.91332	1.30677	0.00055
42	0.913226	1.30927	0.00055
43	0.913163	1.31093	0.00188
44	0.909192	1.40234	0.00133
45	0.908438	1.42253	0.00077
46	0.907999	1.43431	0.00022
47	0.907924	1.43631	0.00369
48	0.907124	1.43953	0.00167

49	0.906935	1.44464	0.00145
50	0.906606	1.45348	0.00088
51	0.906356	1.46019	0.00203
52	0.905305	1.46879	0.00144
53	0.904897	1.47975	0.00088
54	0.904597	1.48785	0.00064
55	0.905067	1.46736	0.00022
56	0.90686	1.44666	0.01074
57	0.933795	0.80305	0.00989
58	0.928749	0.93334	0.00086
59	0.928651	0.93591	0.00902
60	0.925682	1.01343	0.00173
61	0.924899	1.03404	0.00086
62	0.92436	1.04826	0.00643
63	0.924955	1.03255	0.00621
64	0.922138	1.10641	0.00108
65	0.922016	1.10967	0.00086
66	0.921918	1.11228	0.00513
67	0.920685	1.14463	0.00371

68	0.918581	1.20014	0.00229
69	0.917022	1.24146	0.00142
70	0.916619	1.25214	0.00055
71	0.916433	1.25711	0.00086
72	0.920587	1.14725	0.00142
73	0.917534	1.22790	0.00087
74	0.917386	1.23183	0.00055
75	0.917192	1.23699	0.00087
76	0.916323	1.26003	0.00021
77	0.922004	1.11000	0.00085
78	0.932412	0.82045	0.00054
79	0.920499	1.14956	0.00334
80	0.927243	0.96045	0.00251
81	0.926773	0.98524	0.00086
82	0.926724	0.98654	0.00170
83	0.92595	1.04430	0.00124
84	0.925535	1.08964	0.00054
85	0.927573	0.91676	

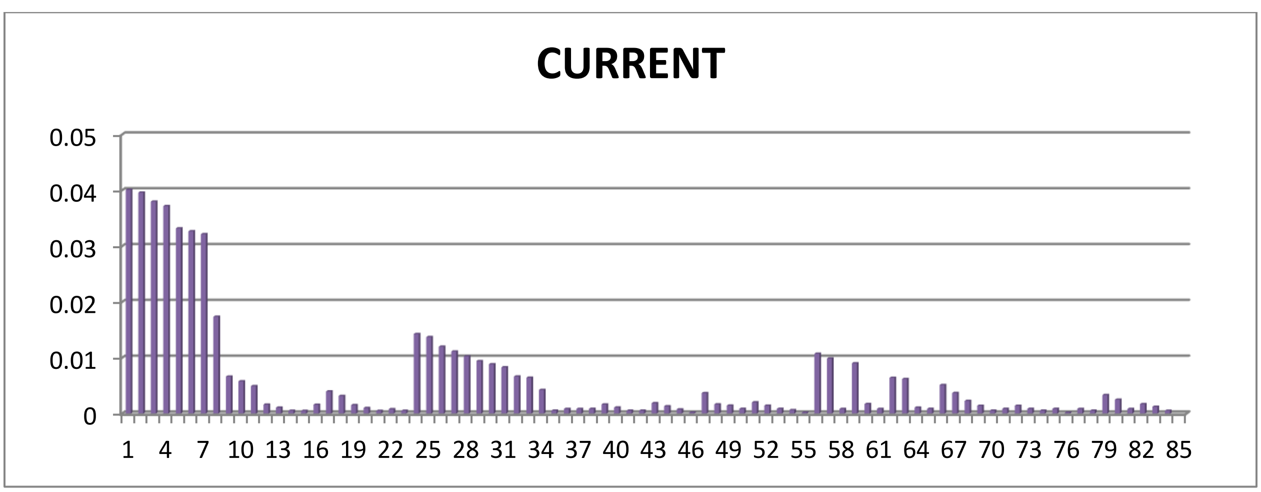

Figure 3.5: Branch Current For Constant Power Load Modeling

Table 3.2: CONSTANT IMPEDANCE FLOW RESULT

Node/ Branch	Voltage	Angle	Current
1	1	0	0.03528
2	0.997155	0.03071	0.03478
3	0.992942	0.07777	0.033194
4	0.987591	0.13820	0.032404
5	0.984994	0.16793	0.028563
6	0.975777	0.27491	0.028071
7	0.970119	0.34191	0.027583
8	0.945651	0.63989	0.015012
9	0.944459	0.65712	0.005788
10	0.941961	0.70494	0.00504
11	0.939994	0.74500	0.004295
12	0.938332	0.78156	0.001418
13	0.937702	0.78913	0.000945
14	0.937512	0.79144	0.000472
15	0.937398	0.79282	0.000503
16	0.996928	0.03627	0.001588
17	0.992493	0.08878	0.003841
18	0.983036	0.21632	0.003054
19	0.981827	0.24631	0.001483
20	0.981407	0.25671	0.000989
21	0.980904	0.26920	0.000494
22	0.980429	0.28102	0.000785
23	0.981738	0.24852	0.000489
24	0.969843	0.34885	0.012109
25	0.942186	0.72238	0.011634
26	0.939524	0.78608	0.010132
27	0.936044	0.86912	0.009384
28	0.934432	0.90755	0.008637
29	0.931462	0.97813	0.007892
30	0.928747	1.04251	0.007424
31	0.927469	1.07275	0.006957
32	0.926671	1.09162	0.005558
33	0.926031	1.10634	0.005373
34	0.923241	1.16995	0.003542
35	0.921799	1.20051	0.000465
36	0.921746	1.20191	0.000751
37	0.939354	0.79049	0.000748
38	0.935578	0.88125	0.000745
39	0.93121	0.98476	0.0014
40	0.926275	1.10202	0.000933
41	0.925693	1.11731	0.000467
42	0.925614	1.1194	0.000467
43	0.925561	1.12078	0.001578
44	0.922257	1.19586	0.001113
45	0.921627	1.21251	0.000649
46	0.92126	1.22223	0.000184
47	0.921197	1.22388	0.003078
48	0.920541	1.22629	0.001397
49	0.920383	1.23049	0.001213
50	0.920109	1.23776	0.000736
51	0.9199	1.24327	0.001691
52	0.919029	1.25025	0.001198
53	0.91869	1.25923	0.000735
54	0.918441	1.26585	0.000538
55	0.918831	1.24908	0.000184
56	0.920321	1.23215	0.009248

57	0.942887	0.69726	0.008494
58	0.938555	0.80822	0.000751
59	0.93847	0.81043	0.007743
60	0.935926	0.87624	0.001496
61	0.935249	0.89387	0.000748
62	0.934783	0.90602	0.005499
63	0.935304	0.89243	0.005312
64	0.932899	0.95486	0.000933
65	0.932793	0.95762	0.000746
66	0.932709	0.95984	0.004379
67	0.931659	0.98710	0.003164
68	0.929868	1.03380	0.001953
69	0.928542	1.06853	0.00121
70	0.9282	1.07751	0.000468
71	0.928041	1.08168	0.000745

72	0.931575	0.98931	0.001211
73	0.928976	1.05717	0.000743
74	0.92885	1.06048	0.000468
75	0.928685	1.06481	0.000742
76	0.927948	1.08413	0.000187
77	0.932783	0.95790	0.000753
78	0.941663	0.71266	0.00047
79	0.9315	0.99127	0.002902
80	0.937177	0.83282	0.002178
81	0.93677	0.85408	0.000749
82	0.936728	0.85520	0.00148
83	0.936057	0.9047	0.001077
84	0.935698	0.94353	0.000473
85	0.937462	0.79538	

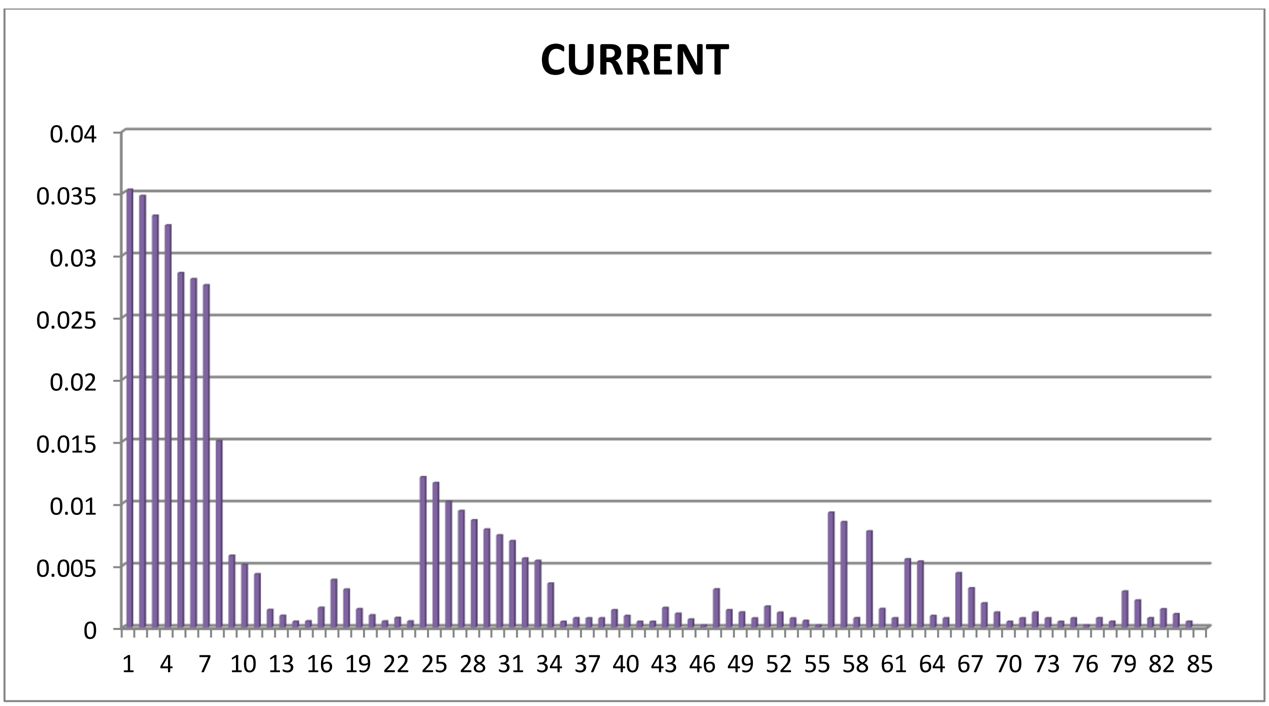

Figure 3.6: Branch Current for Constant Impedance Load Modeling

TABLE 3.3 : CONSTANT CURRENT LOAD FLOW RESULT

Node/ Branch	Voltage	Angle	Current
1	1	0	0.03742
2	0.996982	0.032375	0.036924
3	0.992508	0.082048	0.035324
4	0.986813	0.146023	0.034524
5	0.984045	0.177541	0.030611
6	0.974165	0.291643	0.030107
7	0.968095	0.363238	0.029603
8	0.94183	0.682585	0.016058
9	0.940554	0.701065	0.006172
10	0.937891	0.752284	0.005377
11	0.935793	0.795222	0.004585
12	0.934017	0.834437	0.001512
13	0.933346	0.842544	0.001008
14	0.933143	0.845018	0.000504
15	0.933021	0.8465	0.000504
16	0.996754	0.037952	0.0016
17	0.992055	0.093149	0.003912
18	0.982051	0.226877	0.003112
19	0.980819	0.257465	0.001512
20	0.980391	0.268079	0.001008
21	0.979877	0.280829	0.000504
22	0.979392	0.292897	0.0008
23	0.980728	0.259723	0.000504
24	0.96781	0.37041	0.013058
25	0.938092	0.771729	0.012554
26	0.935218	0.840648	0.010955
27	0.931455	0.930708	0.010155
28	0.92971	0.972443	0.009356
29	0.926492	1.049208	0.008556
30	0.923548	1.119313	0.008053
31	0.922161	1.152265	0.007549
32	0.921295	1.172847	0.006038
33	0.9206	1.188918	0.005838
34	0.917568	1.258397	0.003851
35	0.916	1.291829	0.000504
36	0.915943	1.293354	0.0008
37	0.935037	0.845364	0.0008
38	0.930957	0.943737	0.0008
39	0.926221	1.056361	0.001512
40	0.920868	1.184146	0.001008
41	0.920239	1.200756	0.000504
42	0.920154	1.203025	0.000504
43	0.920097	1.204528	0.001712
44	0.916501	1.28669	0.001208
45	0.915817	1.304876	0.000704
46	0.915419	1.315484	0.0002
47	0.915351	1.317293	0.003349
48	0.914632	1.320047	0.001518
49	0.91446	1.324642	0.001318
50	0.914162	1.332589	0.0008
51	0.913936	1.338615	0.00184
52	0.912986	1.346296	0.001304
53	0.912617	1.356131	0.0008
54	0.912346	1.363392	0.000586
55	0.912771	1.345018	0.0002
56	0.914392	1.326453	0.009912

57	0.938869	0.744223	0.009112
58	0.934222	0.863692	0.0008
59	0.934131	0.866063	0.008312
60	0.931399	0.937026	0.0016
61	0.930675	0.955965	0.0008
62	0.930177	0.969026	0.005912
63	0.930731	0.9545	0.005712
64	0.928144	1.021949	0.001
65	0.928031	1.024932	0.0008
66	0.92794	1.02732	0.004712
67	0.92681	1.056816	0.003408
68	0.92488	1.107378	0.002104
69	0.923452	1.144997	0.001304
70	0.923083	1.154719	0.000504
71	0.922912	1.159244	0.0008

72	0.926719	1.059206	0.001304
73	0.92392	1.132669	0.0008
74	0.923785	1.136255	0.000504
75	0.923606	1.140947	0.0008
76	0.922811	1.161898	0.0002
77	0.92802	1.025233	0.0008
78	0.937575	0.76052	0.000504
79	0.926639	1.061322	0.003099
80	0.932785	0.889441	0.002327
81	0.93235	0.912261	0.0008
82	0.932305	0.91346	0.001582
83	0.931588	0.966605	0.001151
84	0.931204	1.008311	0.000504
85	0.933089	0.849243	

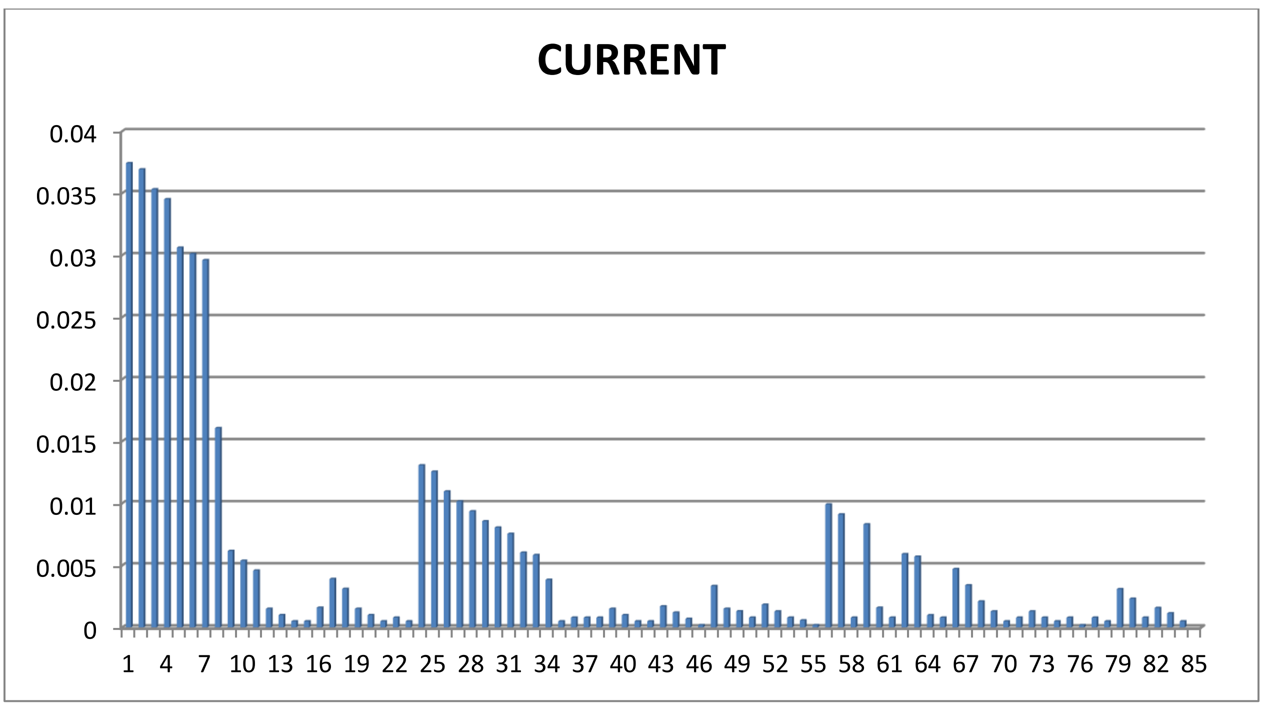

Figure 3.7: Branch Current for Constant Current Load Modeling

TABLE 3.4: ZIP POWER FLOW RESULT

Node/ Branch	Voltage	Angle	Current
1	1	0	0.038245
2	0.996916	0.033001	0.037741
3	0.992342	0.083658	0.036137
4	0.986516	0.148966	0.035333
5	0.983683	0.181161	0.031397
6	0.973548	0.297969	0.030889
7	0.96732	0.371311	0.03038
8	0.940364	0.698827	0.016456
9	0.939057	0.717782	0.006317
10	0.936331	0.770294	0.005505
11	0.934183	0.814329	0.004695
12	0.932365	0.854555	0.001548
13	0.931678	0.862868	0.001032
14	0.93147	0.865405	0.000516
15	0.931345	0.866925	0.000505
16	0.996687	0.038584	0.001604
17	0.991889	0.094788	0.003936
18	0.981676	0.230817	0.003132
19	0.980436	0.261608	0.001522
20	0.980006	0.272295	0.001015
21	0.979489	0.285133	0.000507
22	0.979001	0.297285	0.000805
23	0.980345	0.263882	0.000509
24	0.967032	0.378566	0.013427
25	0.93652	0.790562	0.012912
26	0.933564	0.861516	0.011277
27	0.92969	0.954329	0.010457
28	0.927893	0.997363	0.009638
29	0.924578	1.07656	0.008817
30	0.921543	1.148923	0.0083
31	0.920115	1.182949	0.007782
32	0.919222	1.204206	0.006227
33	0.918505	1.220813	0.006022
34	0.915377	1.292626	0.003974
35	0.913759	1.327198	0.00052
36	0.913701	1.328774	0.000818
37	0.933379	0.866349	0.00082
38	0.929179	0.967702	0.000821
39	0.9243	1.083916	0.001556
40	0.918782	1.215858	0.001037
41	0.918135	1.232988	0.000519
42	0.918047	1.235328	0.000519
43	0.917988	1.236879	0.001765
44	0.914278	1.321859	0.001245
45	0.913572	1.340654	0.000726
46	0.913161	1.351618	0.000206
47	0.913091	1.353488	0.003456
48	0.912347	1.356386	0.001566
49	0.91217	1.361138	0.00136
50	0.911863	1.369357	0.000825
51	0.911629	1.37559	0.0019
52	0.910648	1.383551	0.001346
53	0.910267	1.39373	0.000826
54	0.909987	1.401245	0.000605
55	0.910426	1.382228	0.000206
56	0.9121	1.363011	0.010165

57	0.937329	0.7621	0.009348
58	0.93256	0.884843	0.000819
59	0.932468	0.887274	0.00853
60	0.929664	0.960222	0.001639
61	0.928922	0.979664	0.00082
62	0.928411	0.993075	0.006071
63	0.928977	0.978197	0.005866
64	0.92632	1.047587	0.001026
65	0.926205	1.050653	0.000821
66	0.926112	1.053107	0.00484
67	0.92495	1.083471	0.003502
68	0.922967	1.135531	0.002162
69	0.921499	1.174272	0.00134
70	0.92112	1.184287	0.000518
71	0.920944	1.188947	0.000821
72	0.924857	1.085929	0.00134
73	0.921981	1.16157	0.000822
74	0.921842	1.165263	0.000518
75	0.921659	1.170094	0.000822
76	0.920841	1.191681	0.000205
77	0.926193	1.050962	0.000817
78	0.936008	0.778724	0.000517
79	0.924775	1.088105	0.003174
80	0.931103	0.910986	0.002383
81	0.930657	0.934401	0.000819
82	0.930611	0.935631	0.00162
83	0.929877	0.990168	0.001179
84	0.929484	1.032969	0.000516
85	0.931416	0.869737	

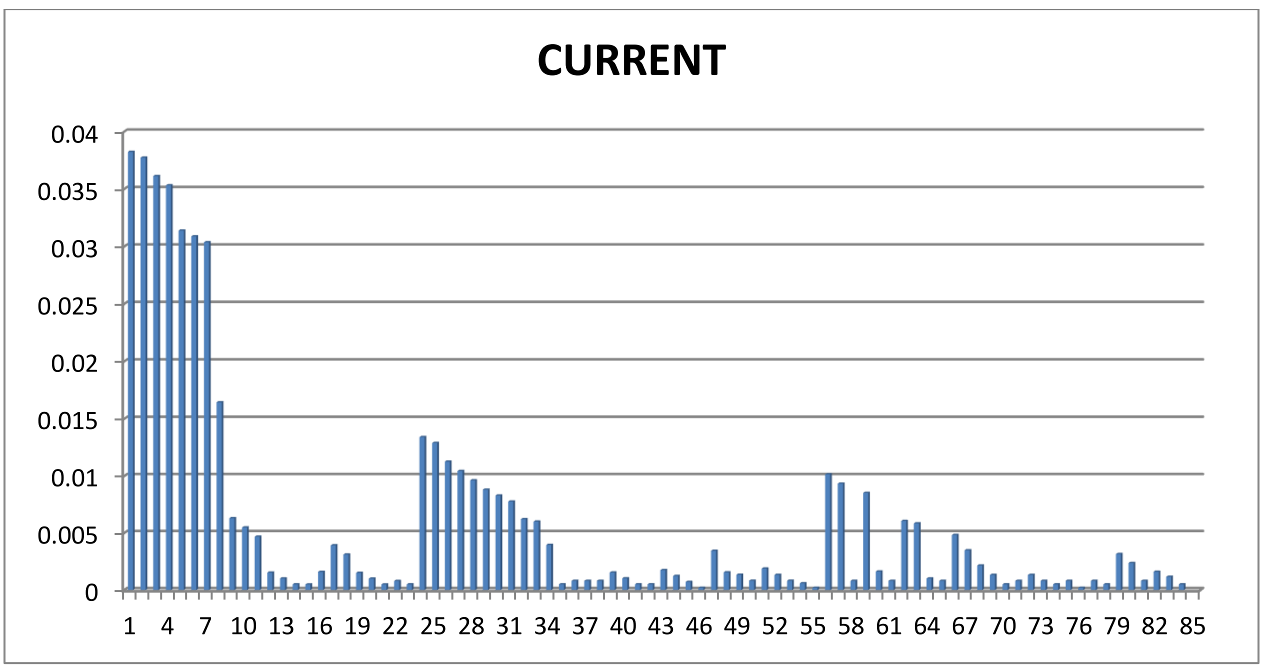

Figure 3.8 : Branch Current for ZIP Load Modeling

3.8 RESULT AND ANALYSIS

The bus voltage of 85 bus system is given in tables (2)-(5) for specific load modeling. Depending upon tolerance value, number of iterations may vary. The convergence tolerance is set at 0.0001. The proposed method took five iterations to give converged solution. The comparison of load models with minimum bus voltage value is given in table (6) that clearly shows that power loss decreases after including the voltage dependent loads than voltage independent loads in the system although the fraction of ZIP constant may vary according to given system.

Voltage profile for various load modeling is given in fig. (5),that clearly shows the effect of voltage dependency in voltage profile of system. The time consuming algorithms, such as the forward/backward substitution of the Jacobian matrix or Y matrix and LU factorization are not required in the proposed method. Thus, the proposed method is robust and efficient. As in the proposed method we require relation matrices (i.e. BIBC and BCBV) for load flow solutions.

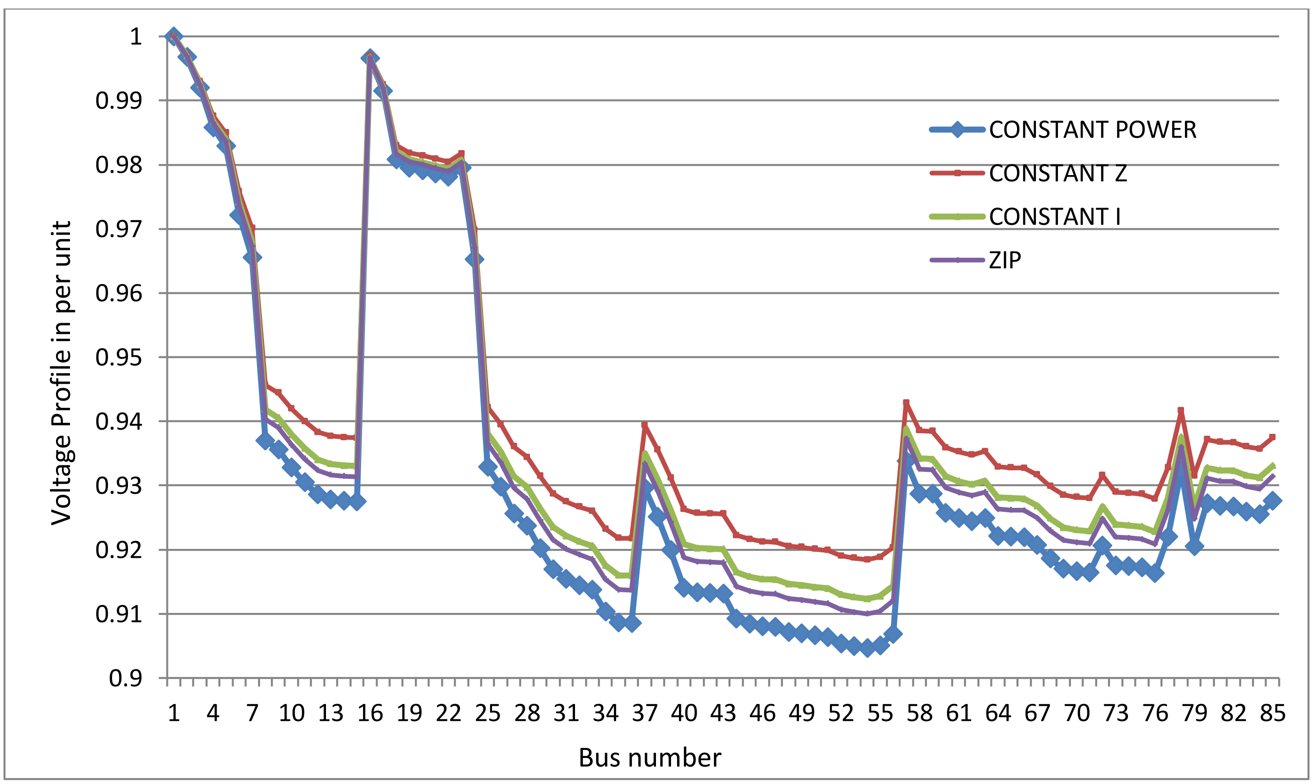

Figure 3.9 : Voltage profile for 85 bus system for specified loads

TABLE 3.5: TOTAL POWER LOSS AND MINIMUM OF BUS VOLTAGE VALUE

Types of Load	**Total real Power loss(kW)**	**Total reactive Power loss (kVAr)**	**Node No.**	**Minimum Voltage value (per unit)**
Constant Power	234.4670	147.8563	54	0.904597
Constant Z	173.9550	109.9251	54	0.918440
Constant I	199.5502	125.9818	54	0.912345
Composite (ZIP)	209.8584	132.4394	54	0.909987

3.9 SUMMARY

An efficient and decent method for load flow calculation is presented in this chapter named forward backward sweep method with the help of BIBC matrix and BCBV matrix. The presented methodology converges for complex power modeling, constant impedance modeling, constant current modeling and composite load modeling. This methodology has been tested for IEEE 85 bus system without tie lines .From the outcomes it is seen that the power loss decreases after including the voltage dependent loads than the voltage independent loads. After this loss evaluation, the various loss minimizing methods and improvement in voltage profile can be applied.

CHAPTER-4

GENETIC ALGORITHM OPTIMIZATION FOR DG

4.1 INTRODUCTION

Optimization is a procedure by which we attempt to discover the best arrangement from set of accessible option. In DG allotment issue, DG areas and sizes must be streamline so that it give most conservative, effective, actually stable distribution framework. When all is said in done distribution frameworks have numerous nodes and it is extremely elusive out the ideal DG area and size by hand. There are various improvement methodologies utilized in the writing. In the introduced section genetic algorithm is utilized as the arrangement procedure.

4.2 Genetic Algorithm

The genetic algorithm is a pursuit calculation that iteratively changes a set (called a population) of scientific articles (regularly fixed-length double character strings), each with a related wellness esteem, into another population of posterity items utilizing the Darwinian rule of common choice and utilizing tasks, for example, crosover (sexual recombination) and mutation[20].

Calculation starts with a lot of arrangements (spoken to by chromosomes) called population. Arrangements from one population are taken and used to frame another population. This is inspired by an expectation, that the new population will be superior to the former one. Arrangements which are then chosen to shape new arrangements (posterity) are chosen by their wellness - the more appropriate they are the more possibilities they need to repeat. This is rehashed until some condition is fulfilled. The space of every single practical arrangement (the arrangement of arrangements among which the ideal arrangement dwells) is called search space (additionally state space). Each point in the hunt space speaks to one conceivable arrangement. Every conceivable arrangement can be "set apart" by its worth (or wellness) for the issue. With GA we search for the best arrangement among various potential arrangements. The issue is that the inquiry can be exceptionally muddled. One may not realize where to search for an answer or where to begin. There are numerous strategies one can use for finding an appropriate arrangement, yet these techniques don't really give the best arrangement. A straightforward hereditary calculation that yields great outcomes in numerous down to earth issues is made out of three administrators:

Reproduction: This operator is an artificial version of natural selection based on Darwinian survival of the fittest among string creatures. Reproduction operator can be implemented in algorithmic form in a number of ways.

Crossover: It happens after propagation or determination. It makes two new population or strings from two existing ones by hereditarily recombining haphazardly picked parts shaped by arbitrarily picked hybrid point.

Mutation: It is the infrequent irregular modification of the estimation of a string position. Change makes another string by adjusting benefit of existing string.

Fitness function: A commonplace hereditary calculation requires two things to be characterized: (1) a hereditary portrayal of arrangements, (2) a fitness function to assess them. The fitness function is characterized over the hereditary portrayal and measures the nature of the spoke to arrangement.

The fitness function is dependably issue subordinate. When we had the hereditary portrayal and the fitness function characterized, GA continues to instate a population of arrangements haphazardly, at that point update it through tedious utilization of mutation, crossover, and selection operators.

4.2.3 GA Parameters:

Crossover probability:

It is the manner by which frequently crossover will be performed. In the event that there is no crossover, posterity are precise of guardians. On the off chance that there is crossover, posterity are produced using portions of both parent's chromosome. In the event that crossover likelihood is 100%, at that point all posterity are made by crossover. In the event that it is 0%, entirely different age is produced using precise of chromosomes from old population. Crossover is made with the expectation that new chromosomes will contain great pieces of old chromosomes and along these lines the new chromosomes will be better.

Mutation probability:

It is the manner by which frequently parts of chromosome will be changed. In the event that there is no mutation, posterity are created following crossover (or straightforwardly replicated) with no change. In the event that mutation is performed, at least one pieces of a chromosome are changed. In the event that mutation likelihood is 100%, entire chromosome is changed, on the off chance that it is 0%, nothing is changed. Mutation for the most part keeps the GA from falling into nearby boundaries. Mutation ought not happen regularly, in light of the fact that then GA will in actuality change to arbitrary hunt.

Population size:

It is what number of chromosomes are in population (in one age). In the event that there are too couple of chromosomes, GA have couple of conceivable outcomes to perform crossover and just a little piece of inquiry space is investigated. Then again, if there are such a large number of chromosomes, GA backs off.

4.3 OBJECTIVE FUNCTION FOR ALLOCATION OF DG:

In each optimization procedure must have an objective function based on that the optimization will proceed. By and large, objective functions are two sort,

(i) Single objective

(ii) Multi objective.

4.4 DG ALLOCATION USING GA OPTIMIZATION:

The principle objective of improvement is to distinguishing the estimating and area of a lot of DG to be acquainted in with the distribution framework. In this distribution framework arranging issue streamlining is finished by hereditary calculation to decide a conservative yet dependable network with better specialized highlights, for example, lower control misfortune, better hub voltage profile, and better branch current/warm farthest point proportion while augmenting DG influence (Pdg) so as to diminish the worry of intemperate dynamic and receptive influence request from transmission networks. Recently talked about a GA is an iterative methodology which starts with an underlying population fundamentally which arbitrarily created.

4.6 GA OPTIMIZATION CASE STUDY :

In the proposed work three different types of DGs are considered as three different cases for the Genetic Algorithm approach to site and size DG in distribution system. The IEEE 85 bus system has been taken into the consideration for the work and the algorithm is developed in "MATLAB© 2018 coding". The constant power load modeling is taken as load model for the proposed algorithm.

Case 1: System performance with only unity power factor DGs;

Case2: System performance with only capacitance type DGs;

Case3: System performance with only synchronous type DGs;

4.6.1 GA Parameter Selection for DG allocation:

To know the impact of the Genetic Algorithm parameter on the enhancement procedure the every single parameter had been change for multiple times and the advancement procedure constantly keep running for 20 time. After finish of two cycles the information are recorded and furthermore make a correlation. In the examination four GA parameters is considered. After the finishing the variety procedure 0.8 and 0.03 are chosen as ideal crossover probability and mutation probability individually for the future enhancement process. Other parameters had been kept same for this procedure.

Table 4.1. Selection of GA parameters

.S. NO.	GENETIC ALGORITHM PARAMETERS	
1	Initial population size	50
2	Maximum number of iteration	20
3	Maximum generation	50
4	Cross over probability	0.8
5	Mutation probability	0.03

4.6.2 GA for Multi-Objective Optimization:

The prime aim of this multi objective optimization is to get the solution of problem formulation with power loss, voltage profile and voltage sensitivity index improvement in a single objective function to optimize power loss of the network as well as the voltage profile of the system. Thus we have three objective functions as (i) the active power loss of the system, (ii) the deviation in voltage and (iii) the voltage sensitivity index. Each of the objective functions has been proposed as ratio such that they are unit less and the combination of the objective functions with their respective penalty constant is taken as the main objective function. The value of penalty constants can be changed according to the requirement and system specification to get the optimized solution. The load flow analysis is done prior to the incorporation of DGs in the system with constant power load modeling. Three DG placement has been shown in the work for different types of DGs. The Network parameters for the different types of DGs have been depicted in table (4.2), (4.3), and (4.4).

TABLE 4.2 CASE (1): UPF DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	2 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

Table4.3: OPTIMIZATION RESULTS USING GA FOR UPF DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE(f1,f2,f3)	COEFFICIENTS
1	47	1.7784	0.4333	0.5
2	29	0.4660	0.08969	0.4
3	45	1.1543	1.02502	0.1

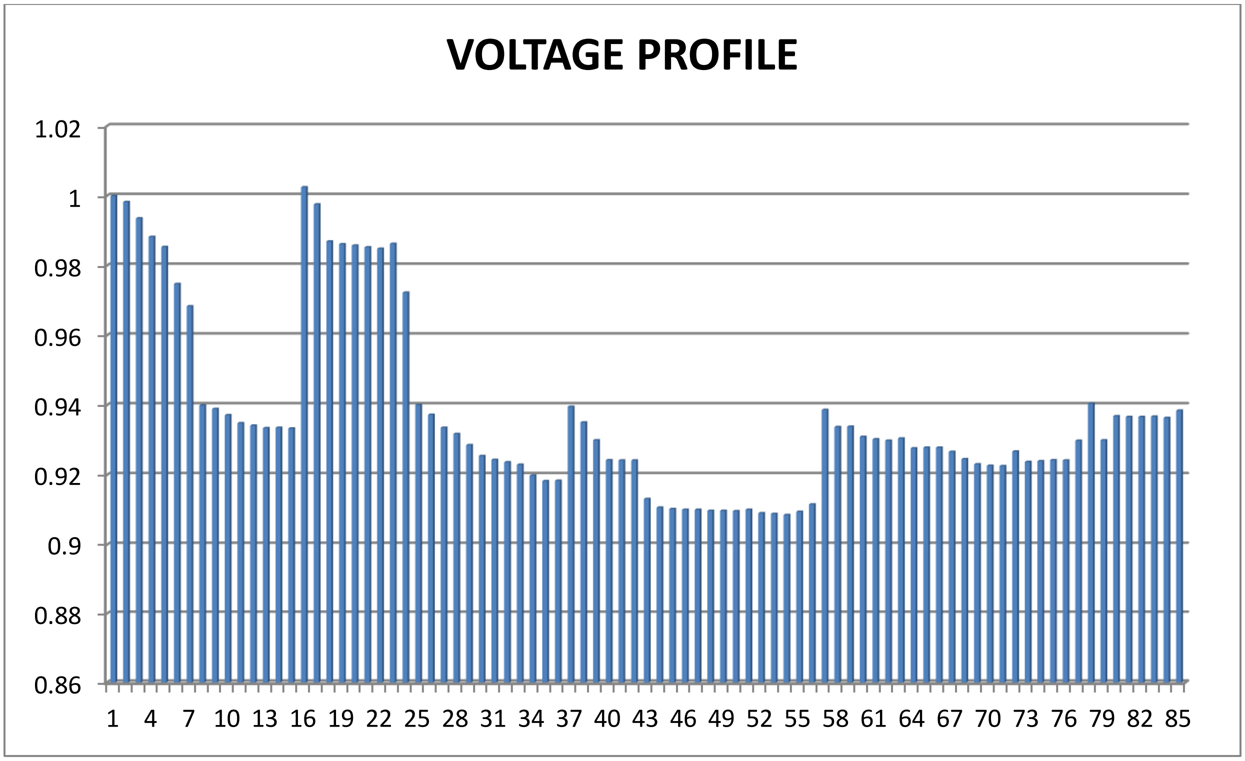

Figure4.1: OPTIMISED VOLTAGE PROFILE USING GA FOR UPF DG

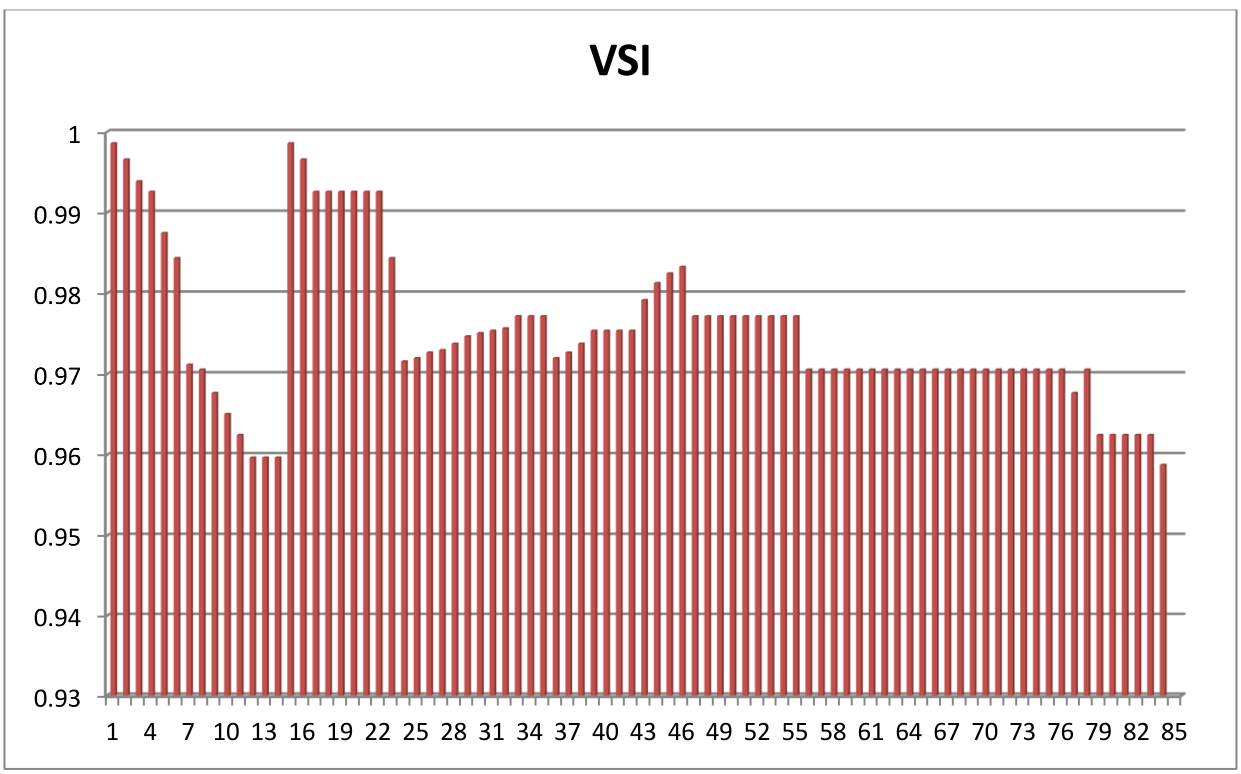

Figure4.2: OPTIMISED VSI USING GA FOR UPF DG

TABLE 4.4: CASE (2) CAPACITOR DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	0.5 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

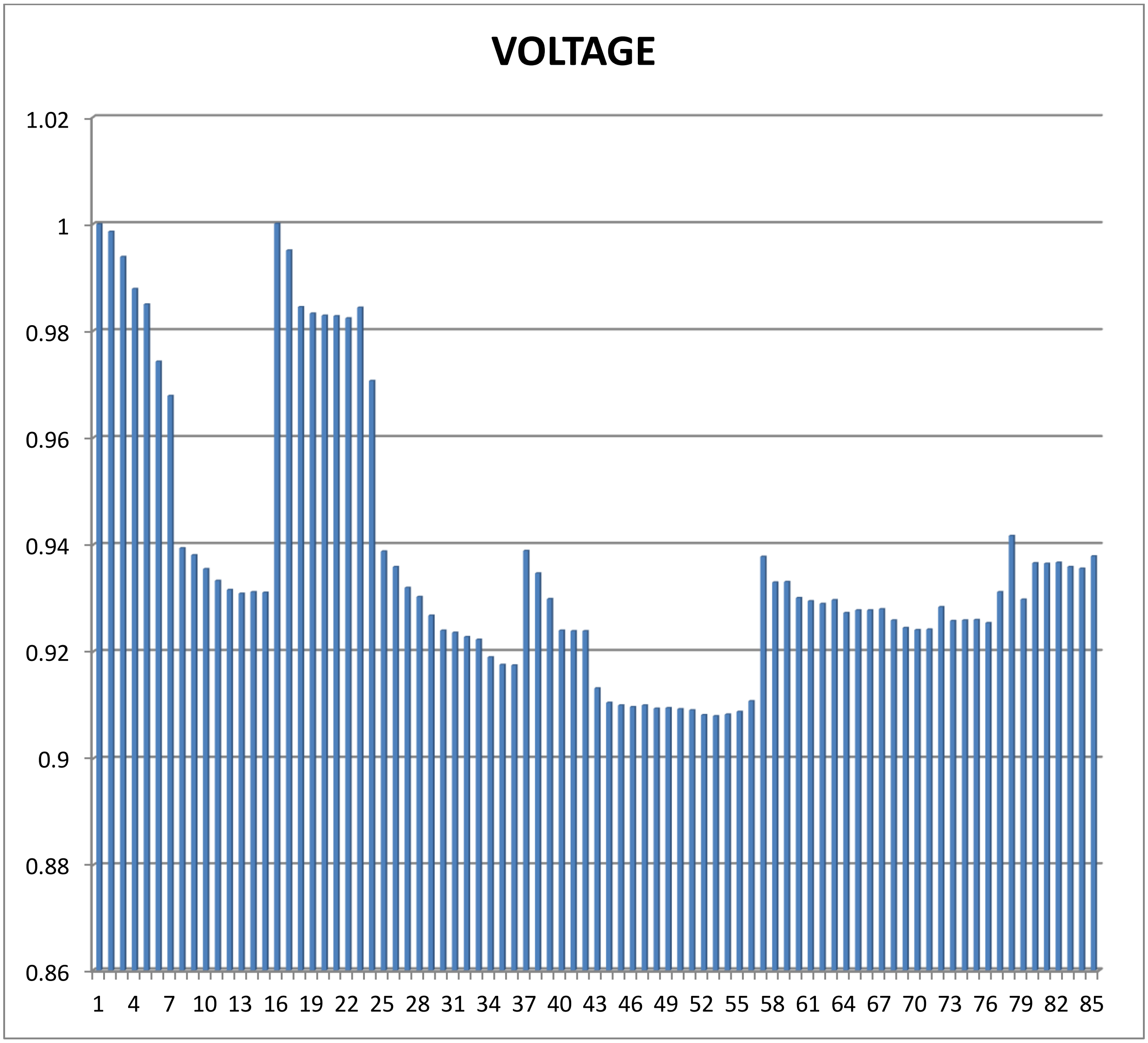

Figure4.3: OPTIMISED VOLTAGE PROFILE USING GA FOR CAPACITOR DG

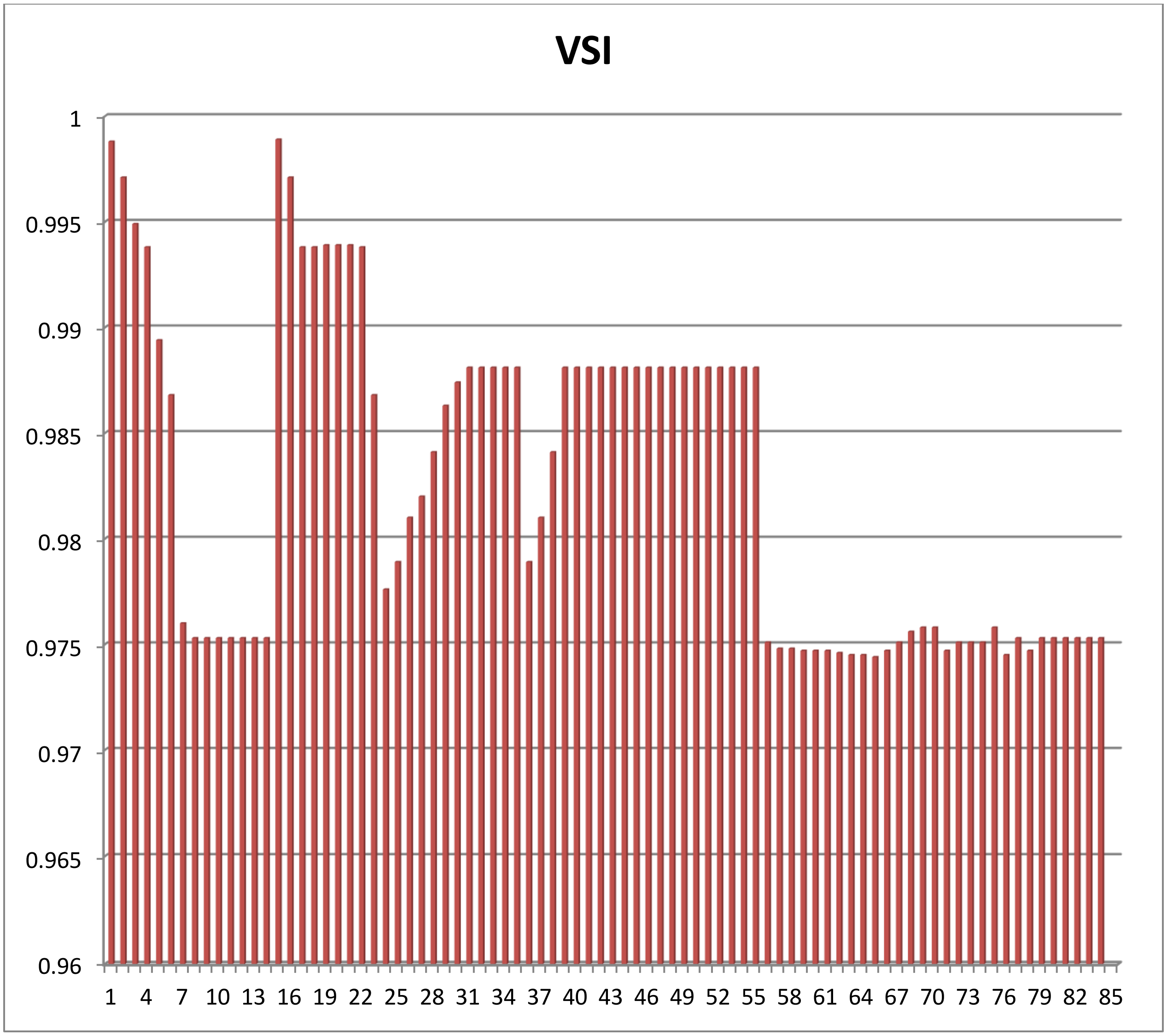

Figure 4.4: OPTIMISED VSI USING GA FOR CAPACITOR DG

Table 4.5: OPTIMIZATION RESULTS USING GA FOR CAPACITOR DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE(f1,f2,f3)	COEFFICIENTS
1	44	0.20411	0.1599	0.5
2	64	0.455023	0.02489	0.4
3	67	0.35647	1.0718	0.1

TABLE 4.4: CASE (3) SYNCHRONOUS DG:-

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	2 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

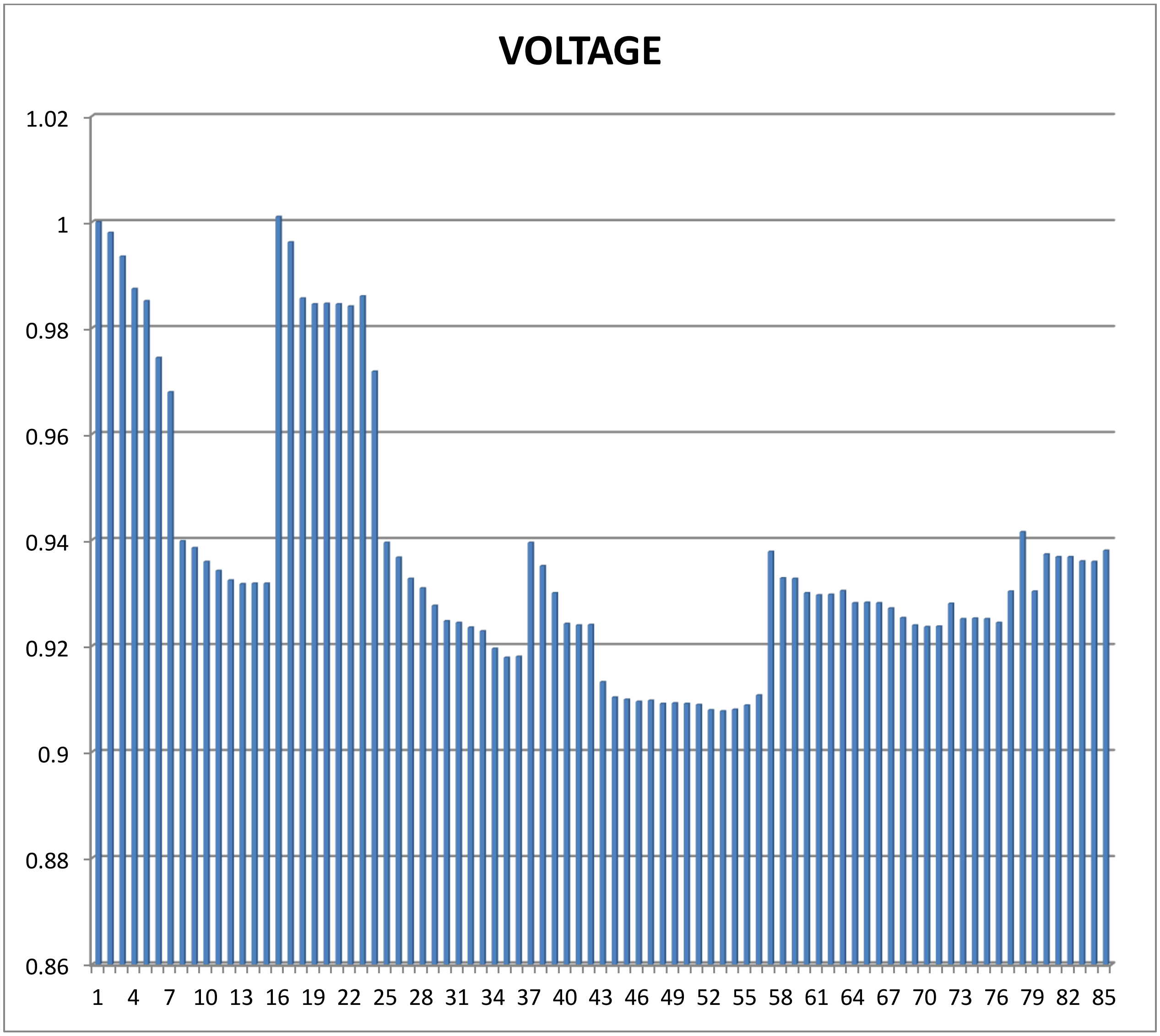

Figure4.5: OPTIMISED VOLTAGE PROFILE USING GA FOR SYNCHRONOUS DG

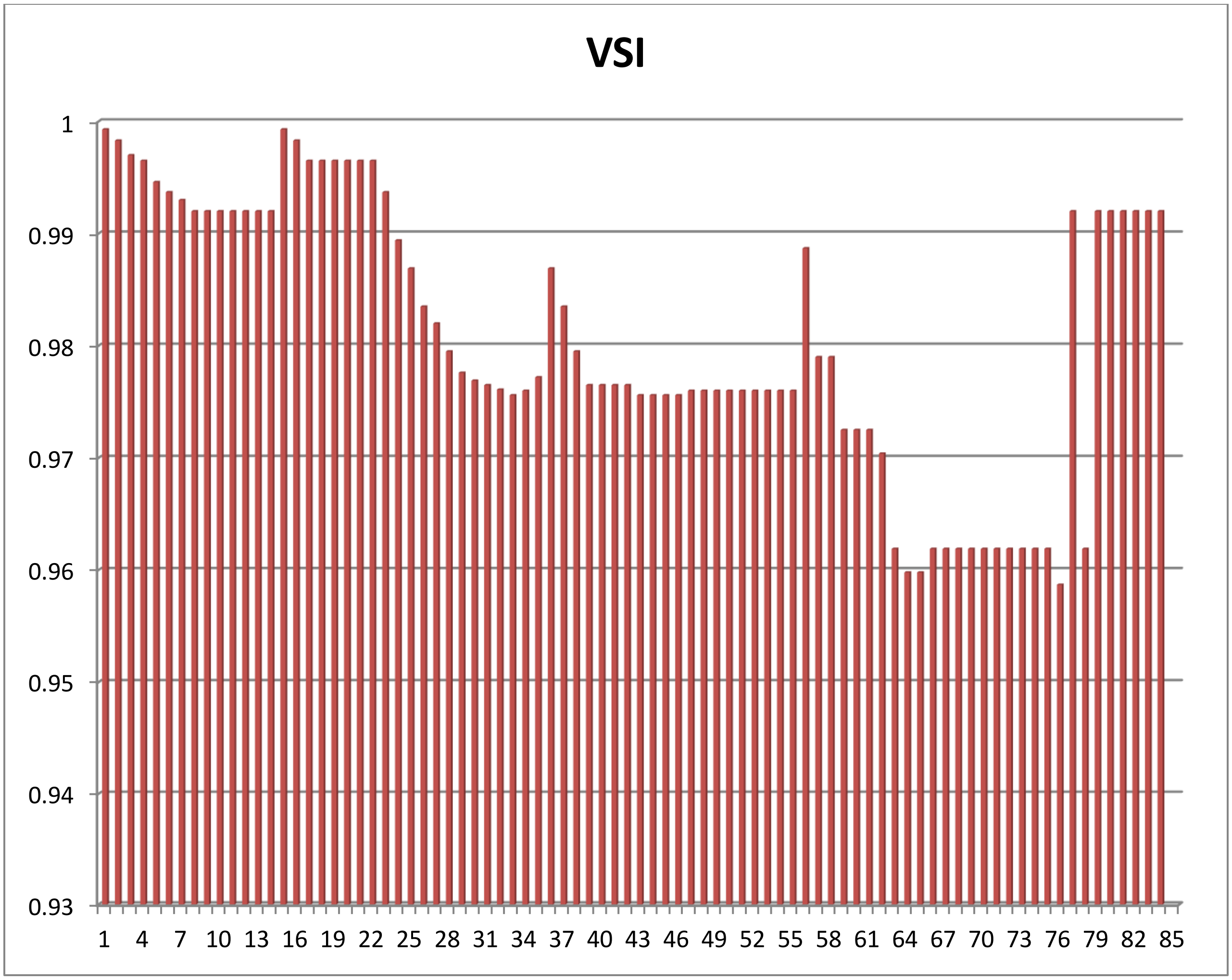

Figure 6: OPTIMISED VSI USING GA FOR SYNCHRONOUS DG

Table 4.5: OPTIMIZATION RESULTS USING GA FOR SYNCHRONOUS DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE(f1,f2,f3)	COEFFICIENTS
1	35	1.4761+ j1.1191	0.251	0.5
2	77	0.9199+ j0.6162	0.070014	0.4
3	36	1.8013+ j1.5165	1.019516	0.1

CHAPTER-5

OPTIMAL DG ALLOCATION USING PARTICLE SWARM OPTIMIZATION

5.1 Introduction

To satisfy the consistently expanding need in the deregulated and rebuilt power system, with the imperatives on new age plants and transmission lines, distributed generation (DG) has developed as a proficient option. Changed government arrangements and expanded accessibility of little limit age advancements are supporting the expanded improvement and organization of conveyed age. Natural concerns have persuaded the utilization of inexhaustible disseminated age. Reconciliation of DG in distribution framework gives huge advantages to the framework, for example, voltage support, misfortune decrease, transmission and distribution limit discharge and improved framework unwavering quality and so on.

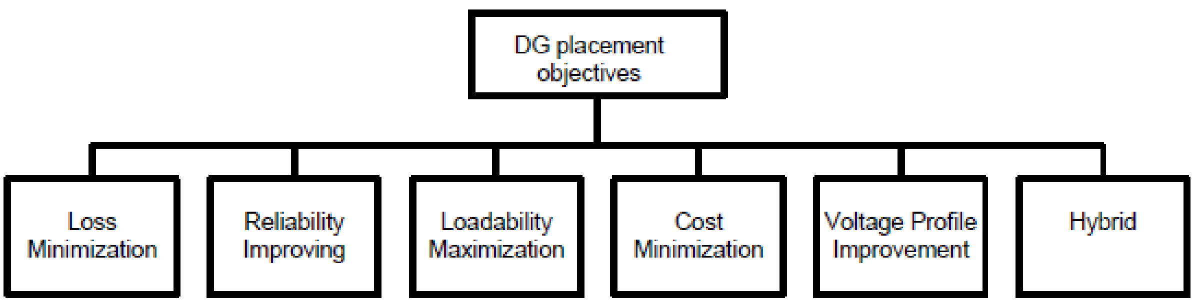

Figure 5.1 DG Placement Objectives

To acquire the reasonable arrangement of this issue, multi-objective function is commonly considered. In such issues encounters have demonstrated that the objectives considered while surrounding the improvement issue are clashing in nature. In such cases, loads are doled out to the individual objectives and these loads are urgently decided relying on the relative significance given to the separate objectives. Numerous multiple times these loads are directed by past involvement, heuristics, administrator's information and so forth to go for a superior exchange off.

5.2 Particle Swarm Optimization

Kennedy and Eberhart first presented particle swarm enhancement (PSO) in 1995 as another heuristic technique. The first goal of their examination was to numerically recreate the social conduct of winged bird flocks and fish schools. As their examination advanced, it was found that with certain alterations, this social conduct model can likewise fill in as an amazing streamlining agent. The main form of PSO was proposed to deal with just nonlinear nonstop enhancement issues. In any case, numerous advances in PSO improvement raised its abilities to deal with a wide class of complex designing and science enhancement issues. Various variations of the PSO calculation have been created by the specialists.

PSO is a computational insight based strategy that isn't to a great extent influenced by the size and non linearity of the issue.

METHODOLOGY OF PSO:

$x_i^k -$ Particle position

$v_i^k -$ Particle velocity

w - Inertia weight

$p_i^k -$ Best "remembered" individual particle position

$p_g^k -$ Best "remembered" swarm position

$c_1, c_2 -$ Cognitive and social parameters

$r_1, r_2 -$ Random numbers between 0 and1

Position of individual particles updated as follows:

$$x_i^{k+1} = x_i^k + v_i^{k+1} \tag{5.1}$$

With the velocity calculated as follows:

$$v_i^{k+1} = w \times v_i^k + c_1 \times rand\left(x_i^k - pb\right) + c_2 \times rand\left(x_i^k - gb\right) \tag{5.2}$$

5.3 Algorithm of Basic PSO

1. Randomly initialize particle positions $x_i^0 \in D$ in IR^n and particle velocities $0 \le v_0^{ix} \le v_0^{\max}$ for $i = 1,......,....p$.

2 Set constants $k_{\max}, c_1, c_2$.

3. Set k = 1.

4. Evaluate function value f_i^k using initial space coordinates x_i^k after determination of objective fitness function.

5. If $f_i^k \le f_i^{best}$ then $f_i^{best} \le f_i^k, p_i^k = x_i^k$ and if $f_i^k \le f_g^{best}$ then $f_g^{best} \le f_i^k, p_g^k = x_i^k$.

6. Update all particle velocities v_i^k and particle positions x_i^k for $i = 1,......,....p$

7. Increment k=k+1.

8. Compare particle‘s fitness evaluation with its previous pbe . If current fitness function value is better than previous pbe , then set current $pbest$ equal to the current position in n-dimensional space.

9. Identify the particle in the neighborhood with the best success so far, and assign its index to the variable gbe .

10. Repeat steps 6-9 until termination criteria is satisfied.

As talked about before, optimization issues engaged with electric distribution framework activity and control are mind boggling and they can be ordered as far as the objective function characteristics or constraints.

PSO technique Characteristics that make it effective are as follows:

- Few algorithm parameters.
- No derivatives are used.
- Effective for global search.
- Easy to implement than other optimization techniques.
- Fitness function in PSO is the Objective function thus direct optimization of problem.

These highlights make the PSO a broadly useful optimizing agent that comprehends a wide scope of advancement issues in distribution frameworks.

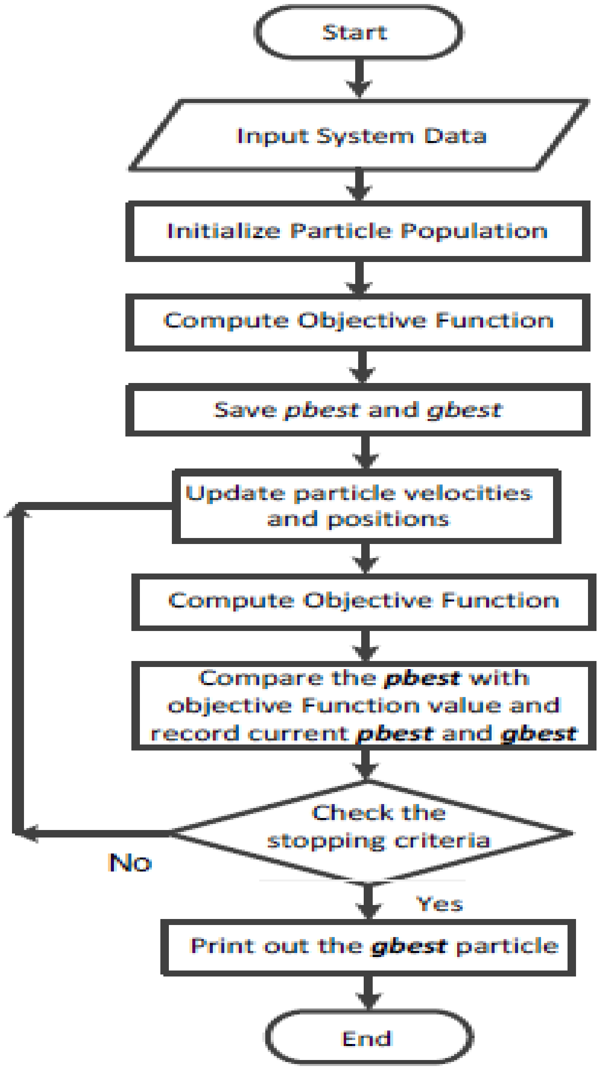

Figure 5.2 Basic PSO Computational Procedure

Table 5.1: PSO PARAMETERS:

.S. NO.	PARTICLE SWARM OPTIMIZATION PARAMETERS	
1	Initial population size	50
2	Maximum number of iteration	20
3	Accelerating coefficient 1	0.1
4	Accelerating coefficient 2	0.1
5	Initial weight	0.9
6	Final weight	0.4

5.4 Results and Discussions

Particle swarm optimization method is used to optimize the objective function given in chapter 1. An 85 bus radial framework is taken into account for various types of DG optimization. The load flow is done by using Backward Forward Sweep method considering constant power load modeling. MATLAB code is formulated to get the solution of various types of DGs for optimization. The network parameters for the calculation have been depicted in table (5.2), (5.3), and (5.3) for the respective cases.

TABLE 5.2: CASE 1: UNITY POWER FACTOR DG

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	2 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

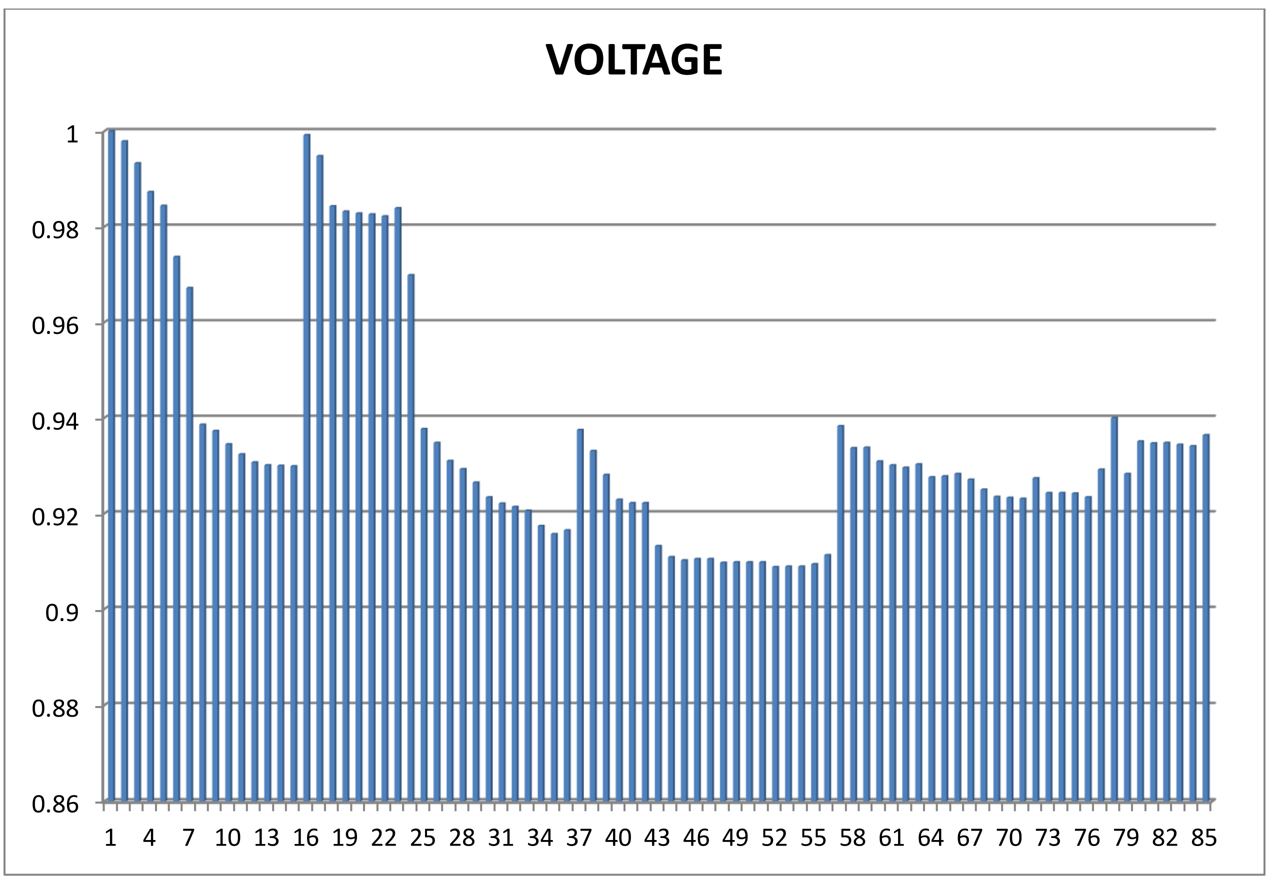

Figure5.1: OPTIMISED VOLTAGE PROFILE USING PSO FOR UPF DG

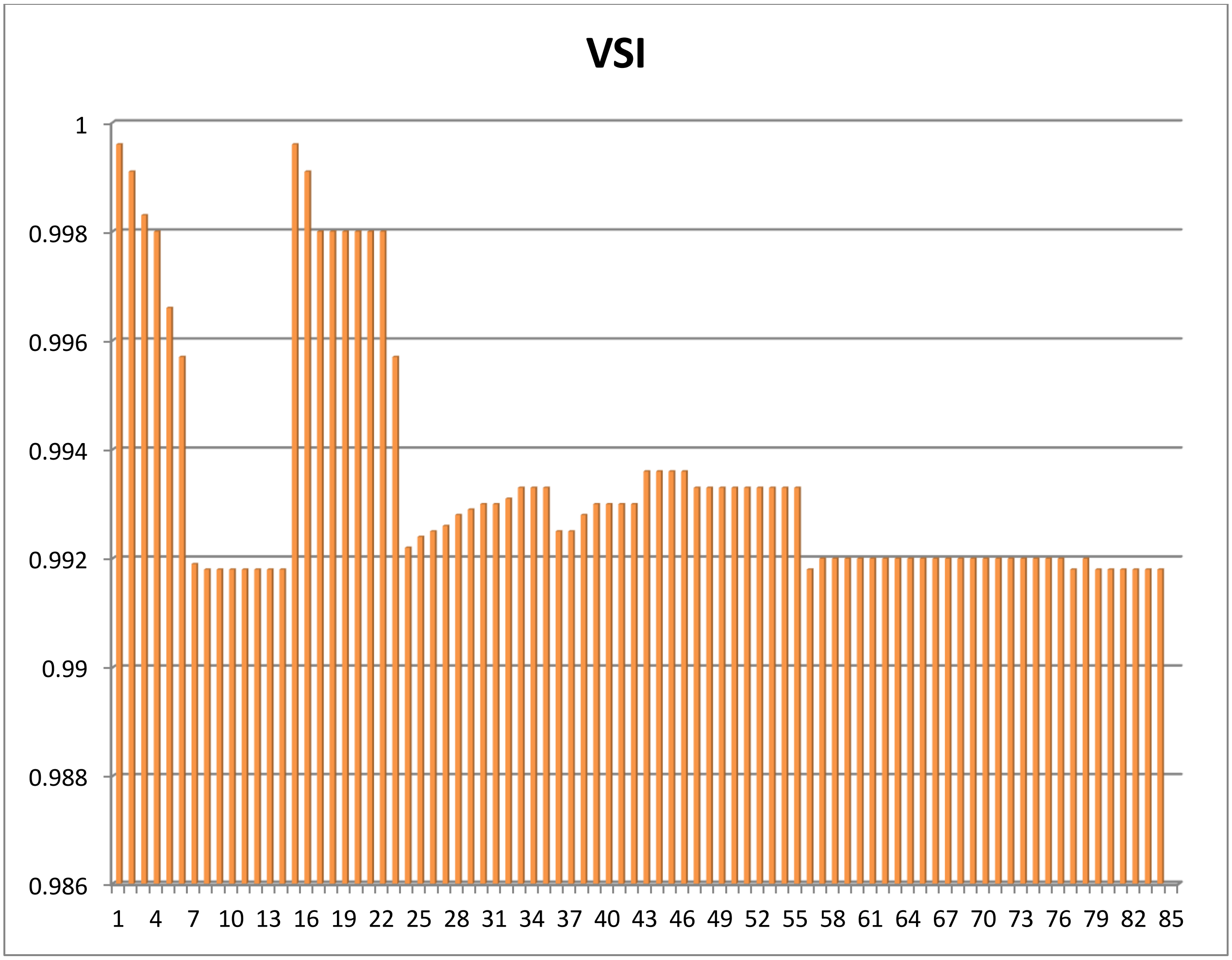

Figure 5.2: OPTIMISED VSI USING PSO FOR UPF DG

Table 5.3: OPTIMIZATION RESULTS USING PSO FOR UPF DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE (f1,f2,f3)	COEFFICIENTS
1	39	1.431435	0.44290	0.5
2	61	1.425641	0.019305	0.25
3	31	1.147537	1.005311	0.25

TABLE 5.4: CASE 2: CAPACITOR DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	0.5 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

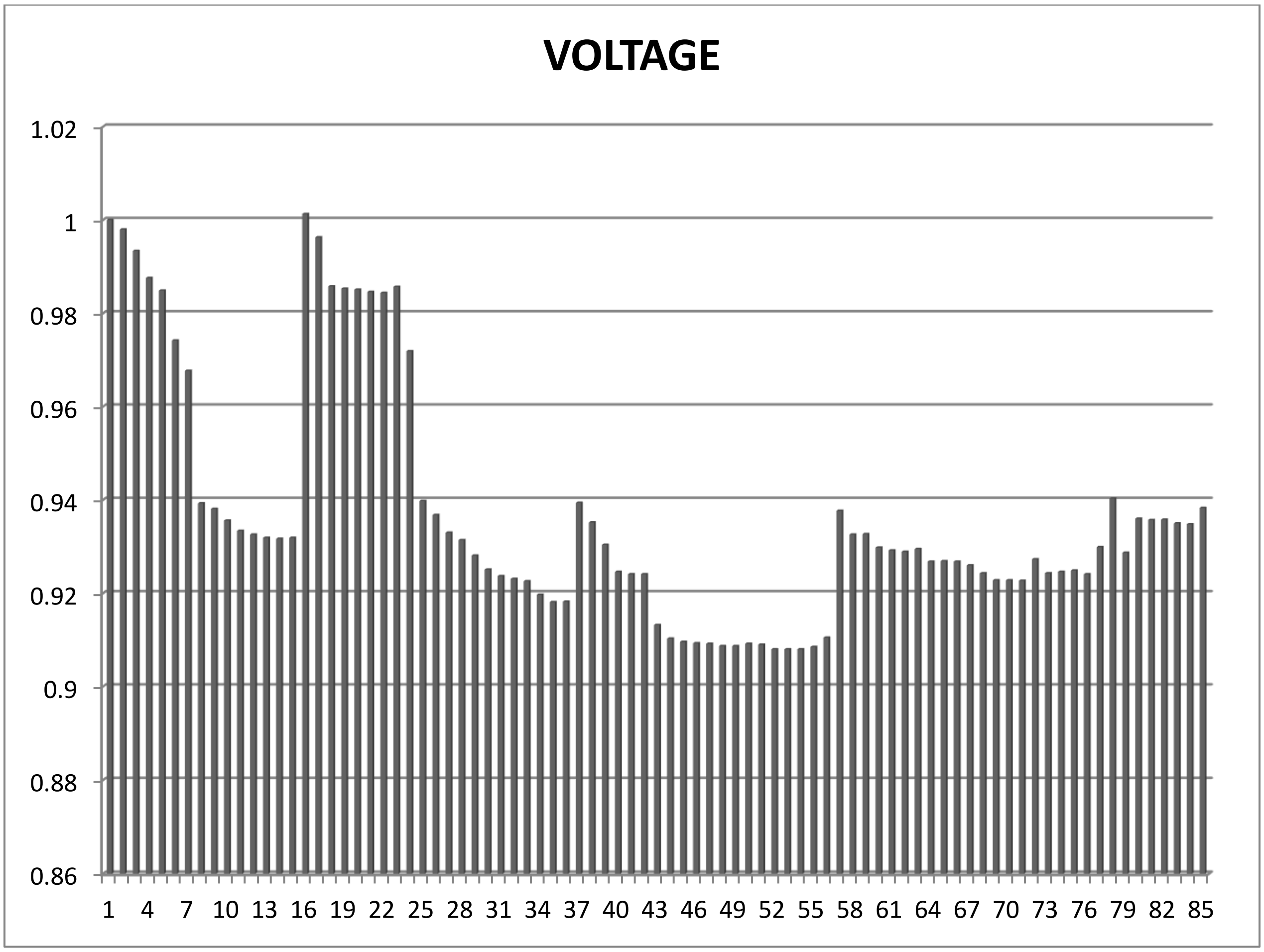

Figure 5.3: OPTIMISED VOLTAGE PROFILE USING PSO FOR CAPACITOR DG

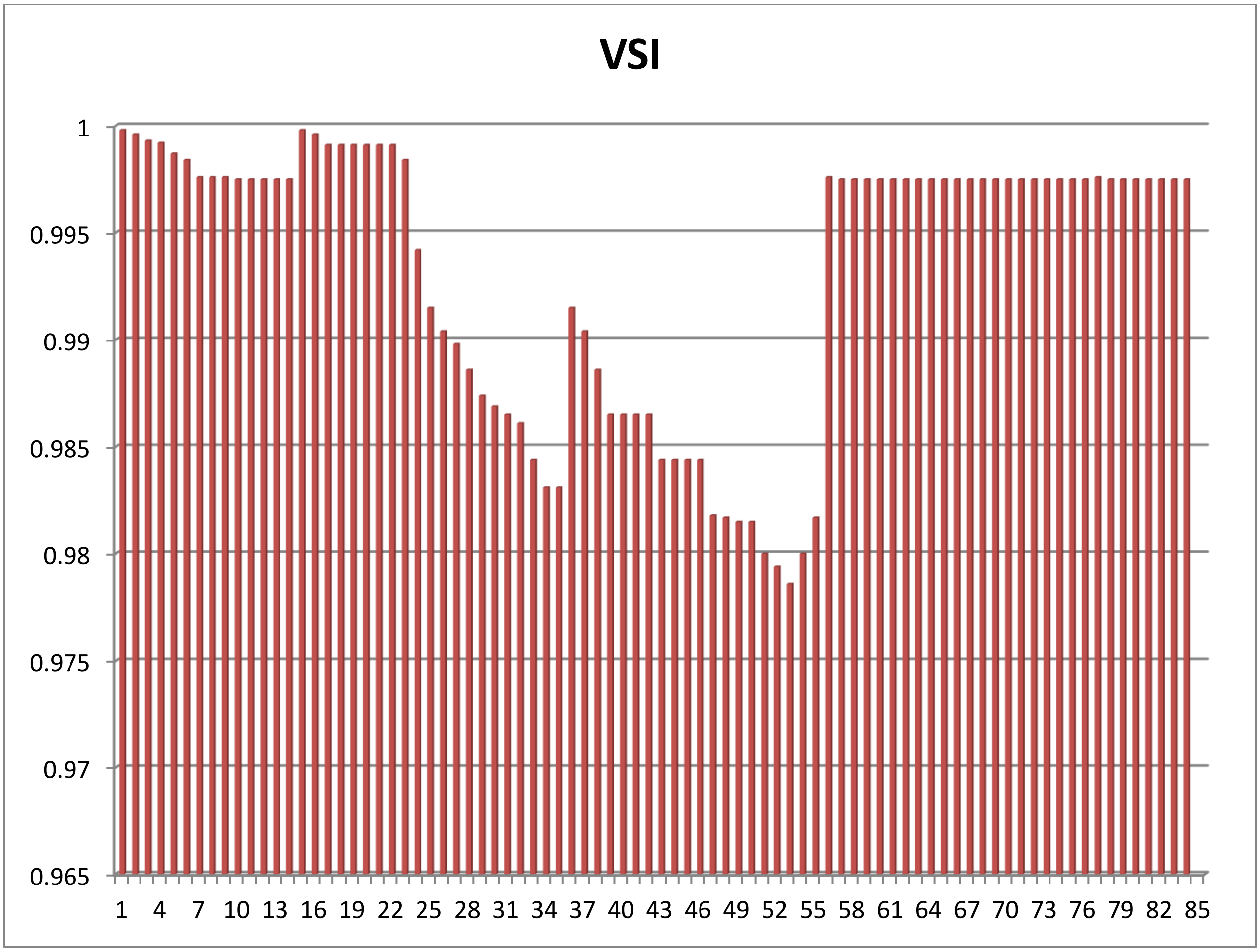

Figure 5.4: OPTIMISED VSI USING PSO FOR CAPACITOR DG

Table 5.5: OPTIMIZATION RESULTS USING PSO FOR CAPACITOR DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE (f1,f2,f3)	COEFFICIENTS
1	54	0.1677	0.1756	0.5
2	50	0.7334	0.0247	0.4
3	26	0.4961	1.0068	0.1

TABLE 5.4: CASE 3: SYNCHRONOUS DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	2 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

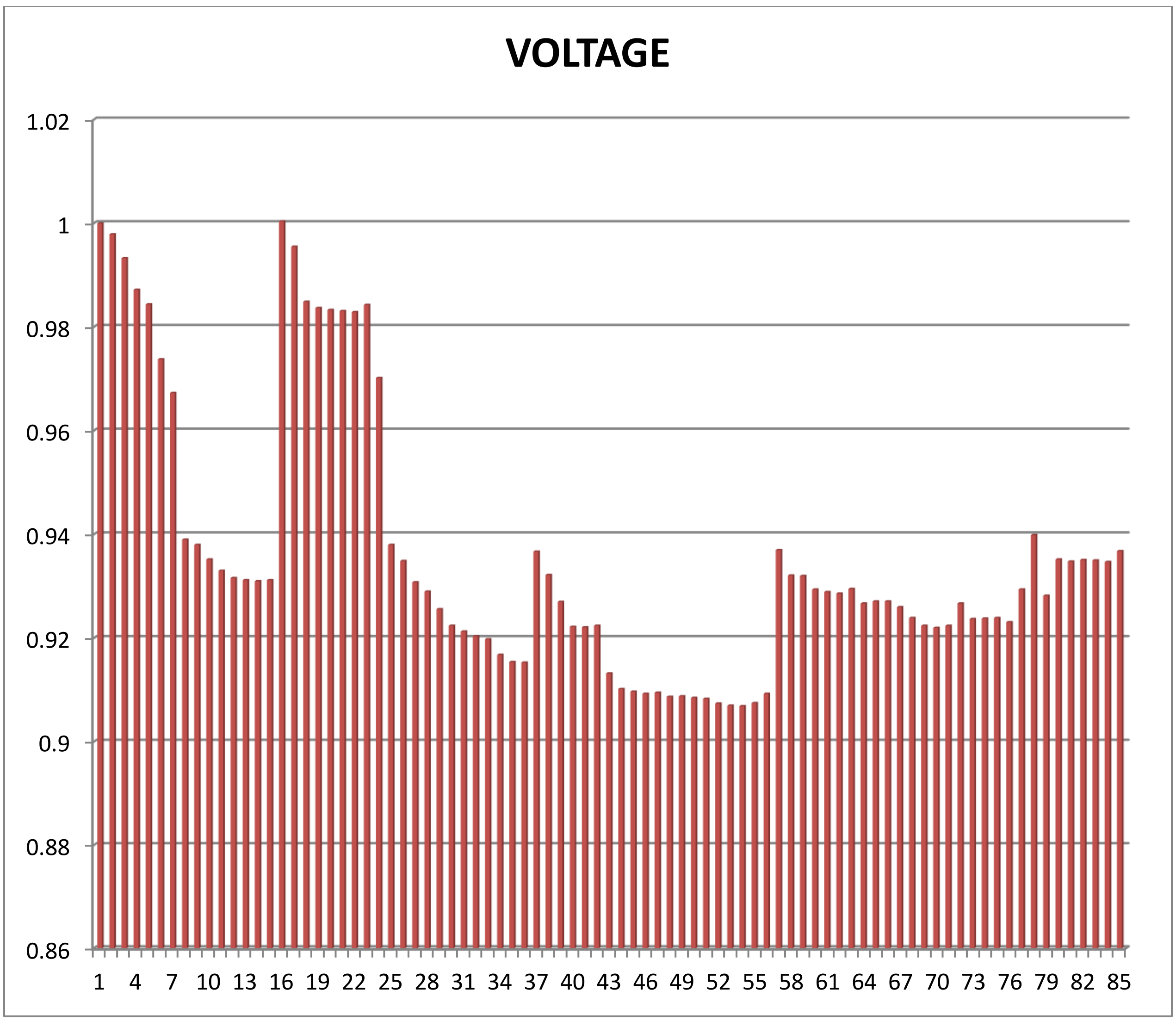

Figure5.5: OPTIMISED VOLTAGE PROFILE USING PSO FOR SYNCHRONOUS DG

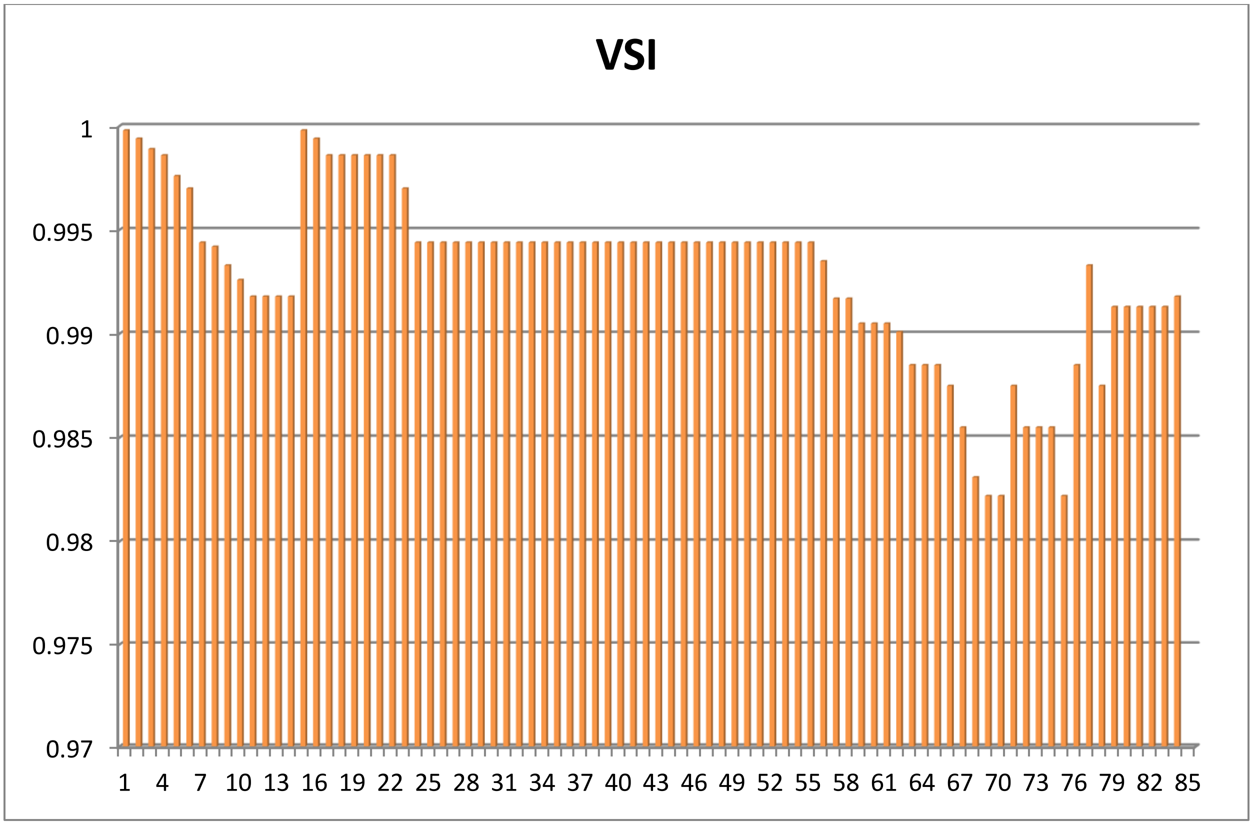

Figure 5.6: OPTIMISED VSI USING PSO FOR SYNCHRONOUS DG

Table5.5: OPTIMIZATION RESULTS USING PSO FOR SYNCHRONOUS DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE(f1,f2,f3)	COEFFICIENTS
1	13	1.7903+ J1.3121	0.65921	0.5
2	14	1.8465+ j1.5334	0.027186	0.4
3	25	0.3153+ j1.2524	1.007501	0.1

CHAPTER-6

OPTIMAL DG ALLOCATION USING HYBRID GA-PSO OPTIMIZATION

6.1 INTRODUCTION:

The fundamental objective of this section is to display a hybrid procedure named as a PSO-GA for taking care of the obliged optimization issues. In this calculation, particle swarm enhancement (PSO) works toward improving the vector while the Genetic Algorithm (GA) has been utilized for changing the decision vectors utilizing hereditary administrators. The harmony among investigation and abuse capacities has been additionally improved by consolidating the hereditary administrators, to be specific, crossover and mutation in PSO calculation.

6.2 METHODOLOGY

The main idea behind this proposal is, after the fitness evaluations are made for each parent in the present population, selection will be done using roulette wheel and two parents are selected based on their fitness ranking and crossover will be performed. In this crossover, two parents will share their chromosomes to produce two off-springs, which will be the new parent in the next generation.

Unlike this regular crossover, which will lead to possible dramatic change in search direction due to crossover exchange, among this two parents the best individual will be used as g_{best} and the other one will be retained as p_{best}. Thus only one parent will be disturbed and produced by this operation derived from PSO. This will help the hybrid algorithm to search the space exhaustively [18]. Additionally this PSO operation will not be done for the entire crossover phase, instead a random of 50% in the beginning stage and gradually reduced to 5% of the total population in the entire run of the algorithm.

$$rndprnt = ((0.5 - 0.05)/\max iter) \times iter \quad (6.1)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (6.2)$$

$$v_i^{k+1} = v_i^k + c_1 \times rand\left(x_i^k - pb\right) + c_2 \times rand\left(x_i^k - gb\right) \tag{6.3}$$

As an example, let us assume two parents are selected for crossover as shown in Fig 1. The fitness value for parent A, B and offspring is 13458, 8889, 8850 respectively. Now instead of this, we use a velocity equation to update the position of parent B using the idea derived from PSO and the equation is given for reference.

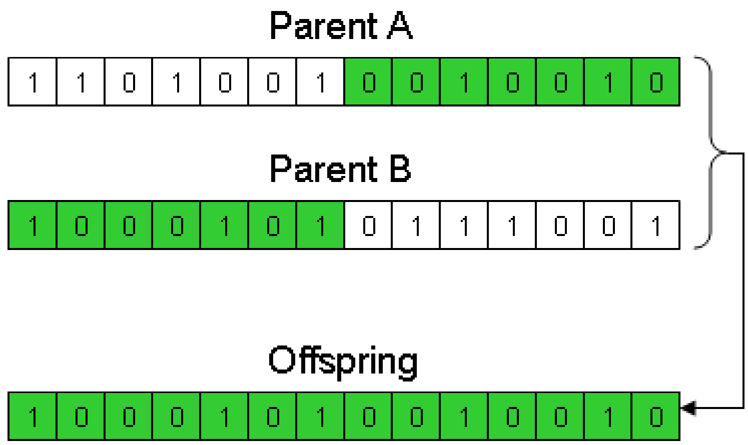

Figure 6.1 (a). Crossover operation in GA

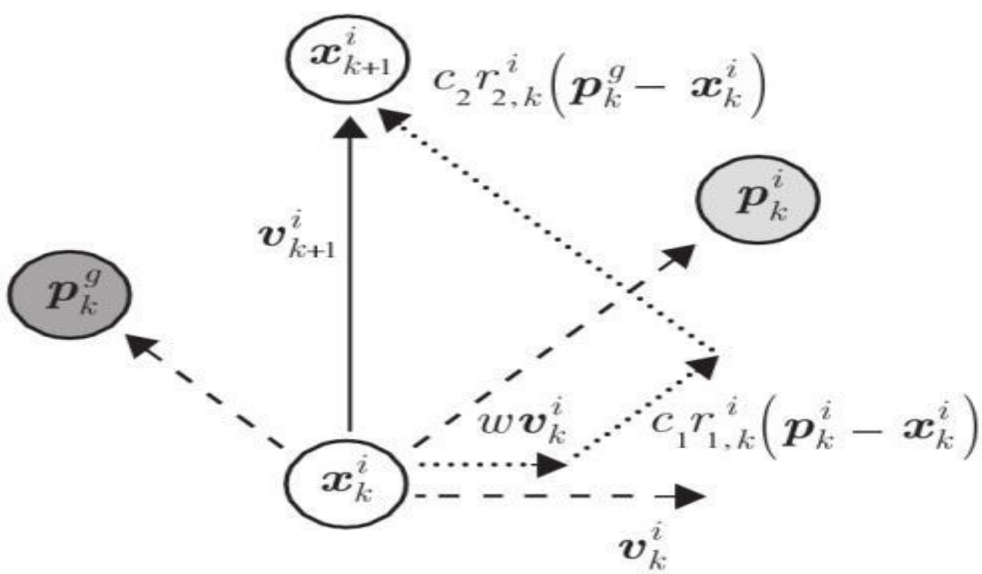

Figure 6.1 (b). Velocity and position update in PSO

Here the g_{best} is 13458, p_{best} is 8889. With regular parameter setting the new position for parent B will be estimated as 7452 using the velocity and position update equation in (1 & 2). Thus the possibility of arriving at better results will be large when going for this hybridization approach. Thus the proposed shift of production of new population in GA will be guided by PSO with a 50% probability is established. A detailed flowchart of the proposed hybrid GA-PSO algorithm is shown in figure 6.2.

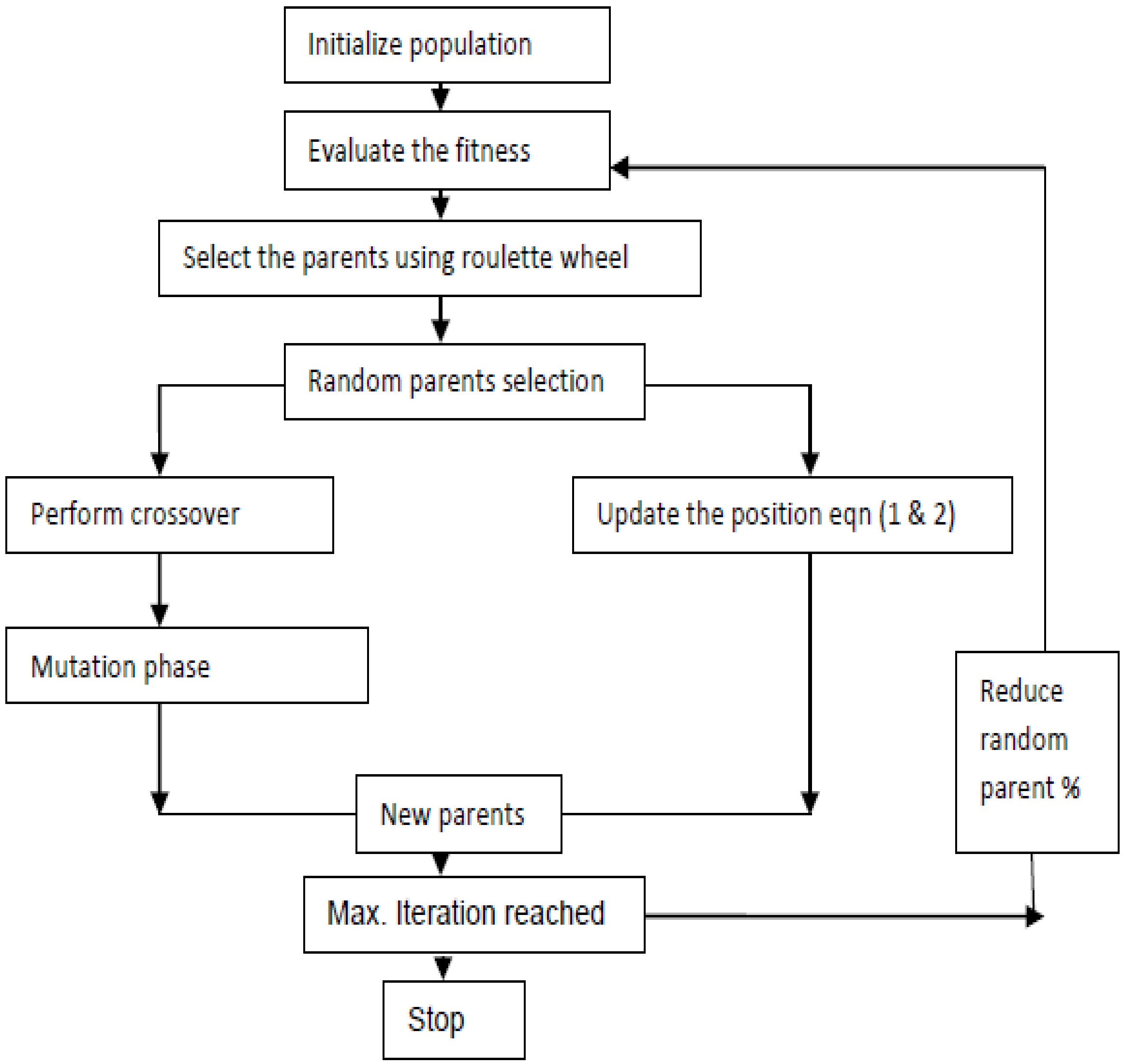

Figure 6.2. Flowchart of the proposed hybrid GA-PSO

Table 6.1: HYBRID GA PSO PARAMETERS:

.S. NO.	HYBRID GA PSO PARAMETERS	
1	Initial population size	50
2	Maximum number of iteration	20
3	Accelerating coefficient 1	0.1
4	Accelerating coefficient 2	0.1
5	Initial weight	0.9
6	Final weight	0.4
7	Maximum generation	50
8	Crossover probability	0.8
9	Mutation probability	0.03

6.2 RESULT AND DISCUSSION:-

TABLE 6.2: CASE (1) CAPACITOR DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	0.5 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

Table6.3: OPTIMIZATION RESULTS USING HYBRID GA PSO FOR CAPACITOR DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE (f1,f2,f3)	COEFFICIENTS
1	45	0.36724	0.061408	0.5
2	39	0.45312	0.010895	0.4
3	59	0.14762	1.002992	0.1

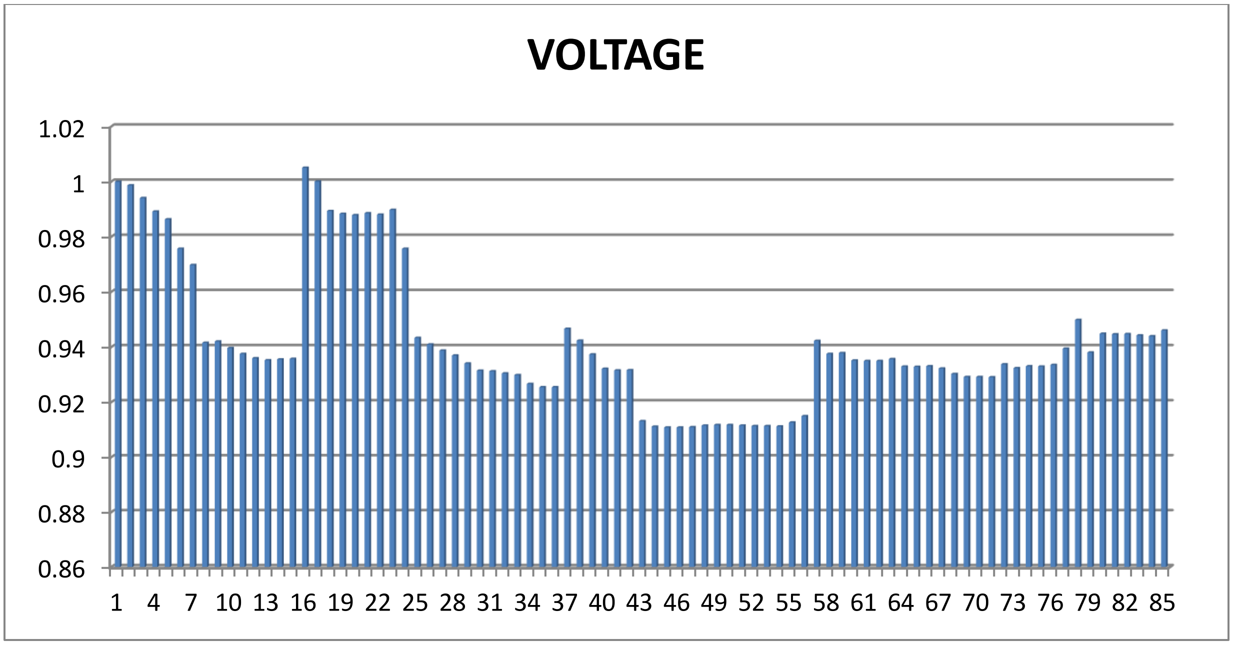

Figure 6.1: OPTIMISED VOLTAGE PROFILE USING HYBRID GA PSO FOR CAPACITOR DG

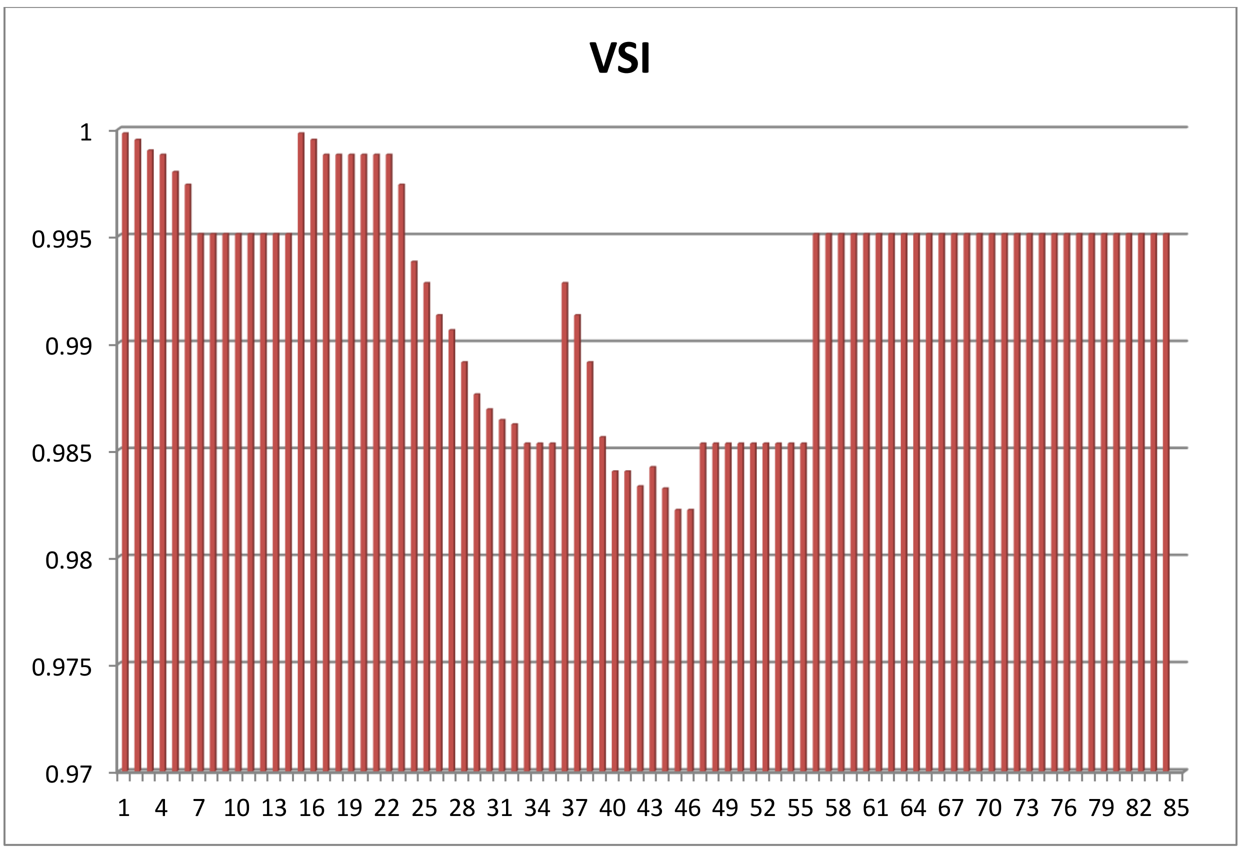

Figure 6.2: OPTIMISED VSI USING HYBRID GA PSO FOR CAPACITOR DG

TABLE 6.4: CASE 2 UPF DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	2 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

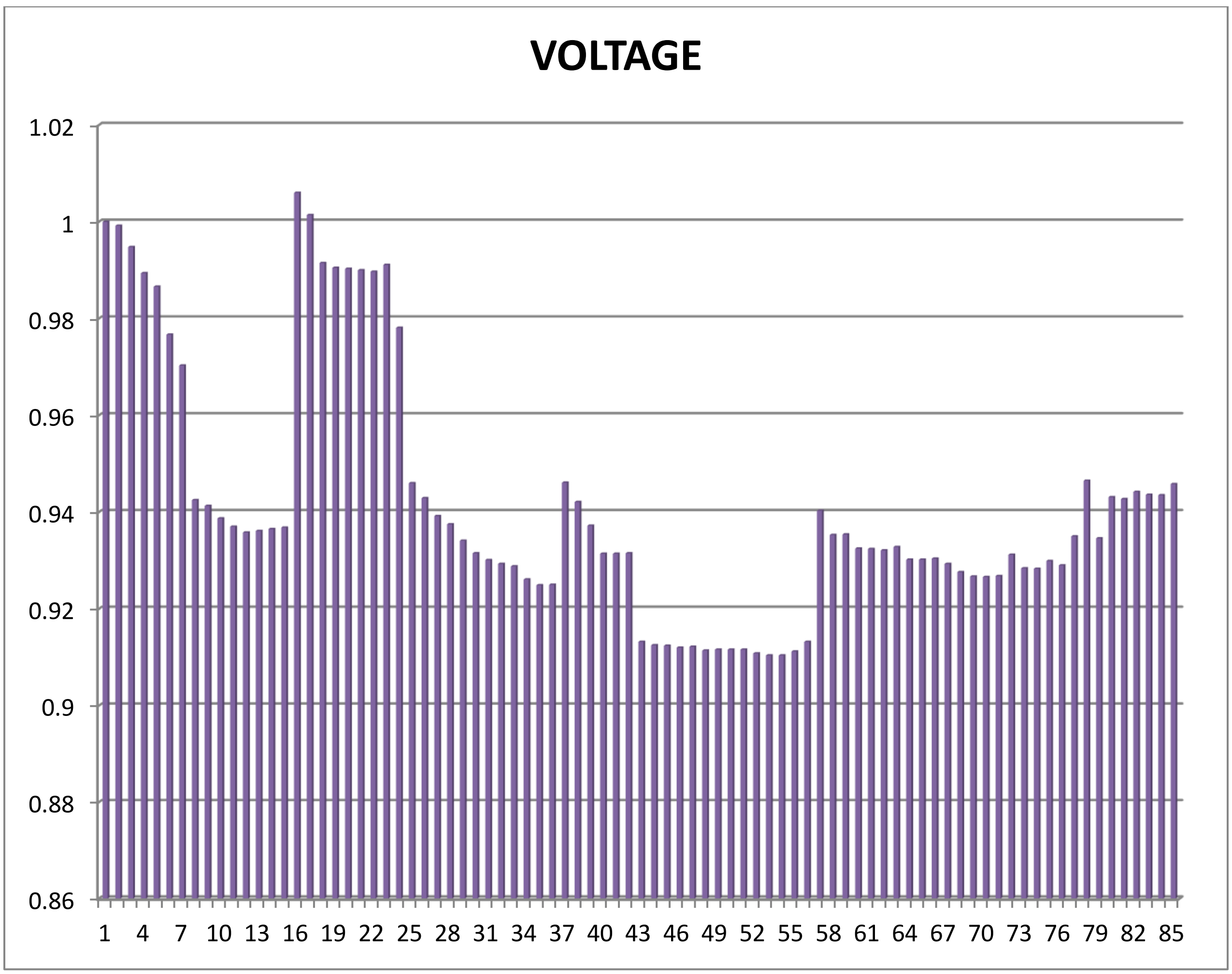

Figure 6.3: OPTIMISED VOLTAGE PROFILE USING HYBRID GA PSO FOR UPF DG

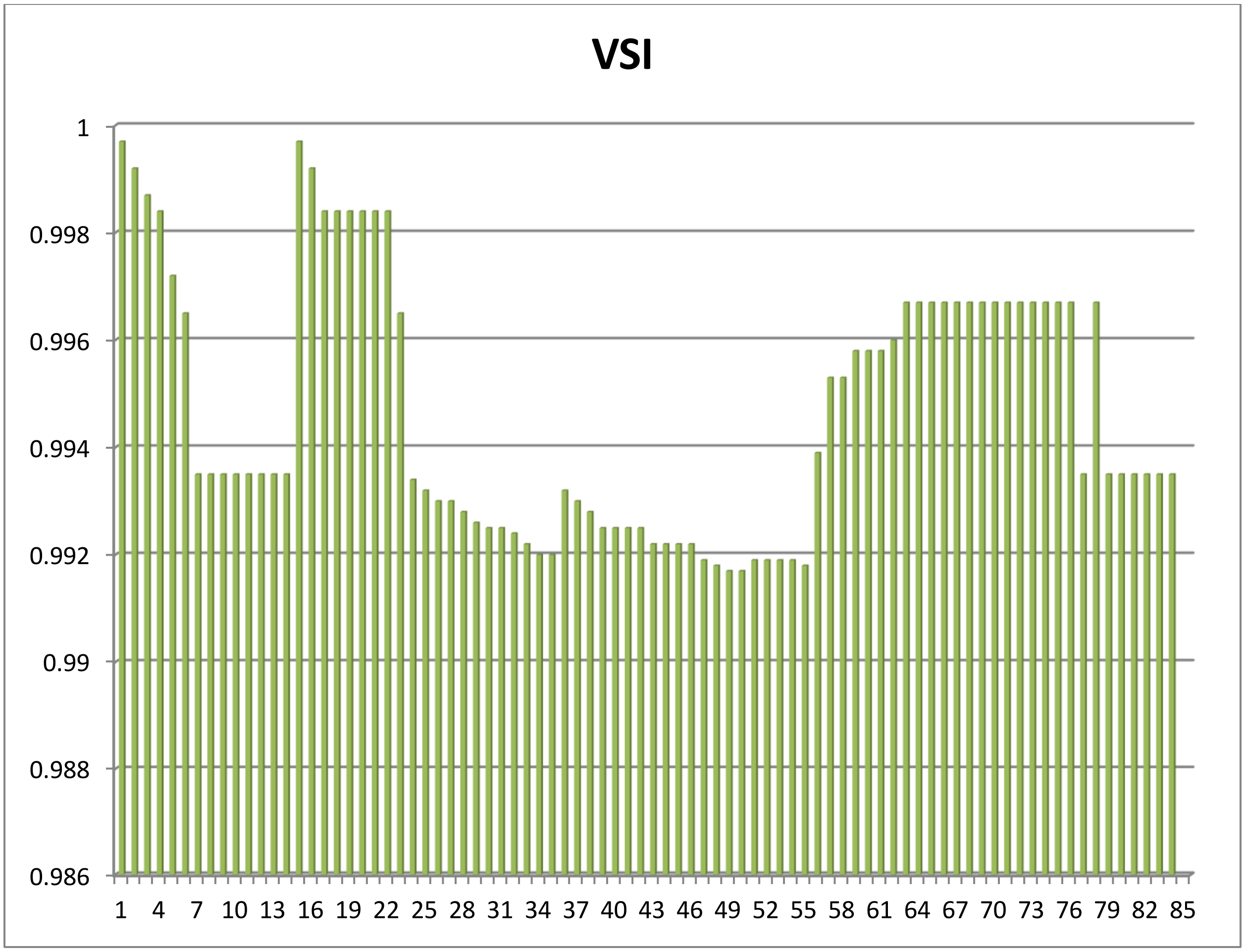

Figure 6.4: OPTIMISED VSI USING HYBRID GA PSO FOR UPF DG

Table 6.5: OPTIMIZATION RESULTS USING HYBRID GA PSO FOR UPF DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE (f1,f2,f3)	COEFFICIENTS
1	39	1.431435	0.44290	0.5
2	61	1.425641	0.019305	0.25
3	31	1.147537	1.005311	0.25

Table 6.6: CASE 3 SYSNCHRONOUS DG:

.S. NO.	NETWORK PARAMETERS	
1	Minimum DG range	10 KVA
2	Maximum DG range	2 MVA
3	Number of DGs	3
4	Load model	Constant power load modeling

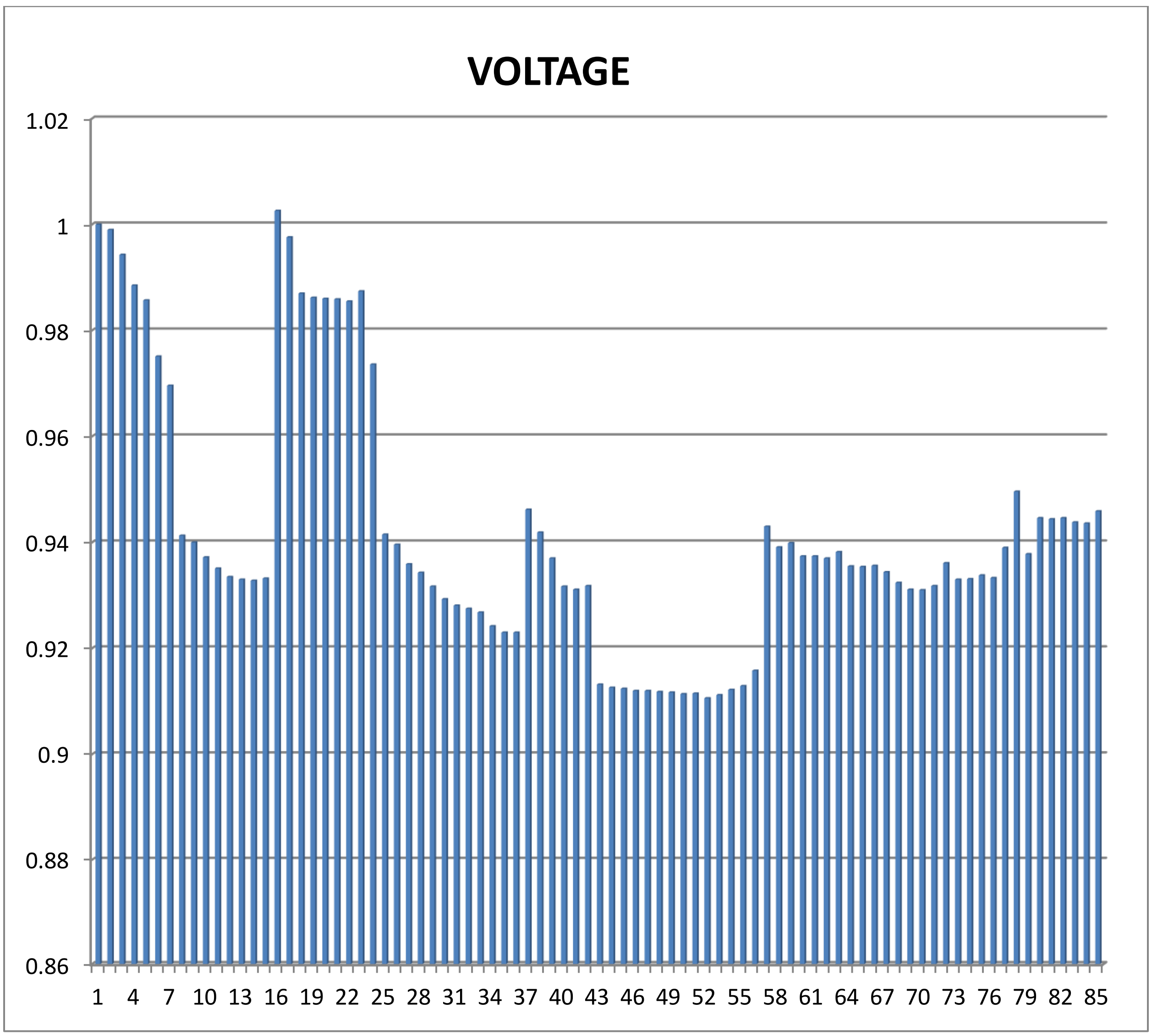

Figure 6.5: OPTIMISED VOLTAGE PROFILE USING HYBRID GA PSO FOR SYNCHRONOUS DG

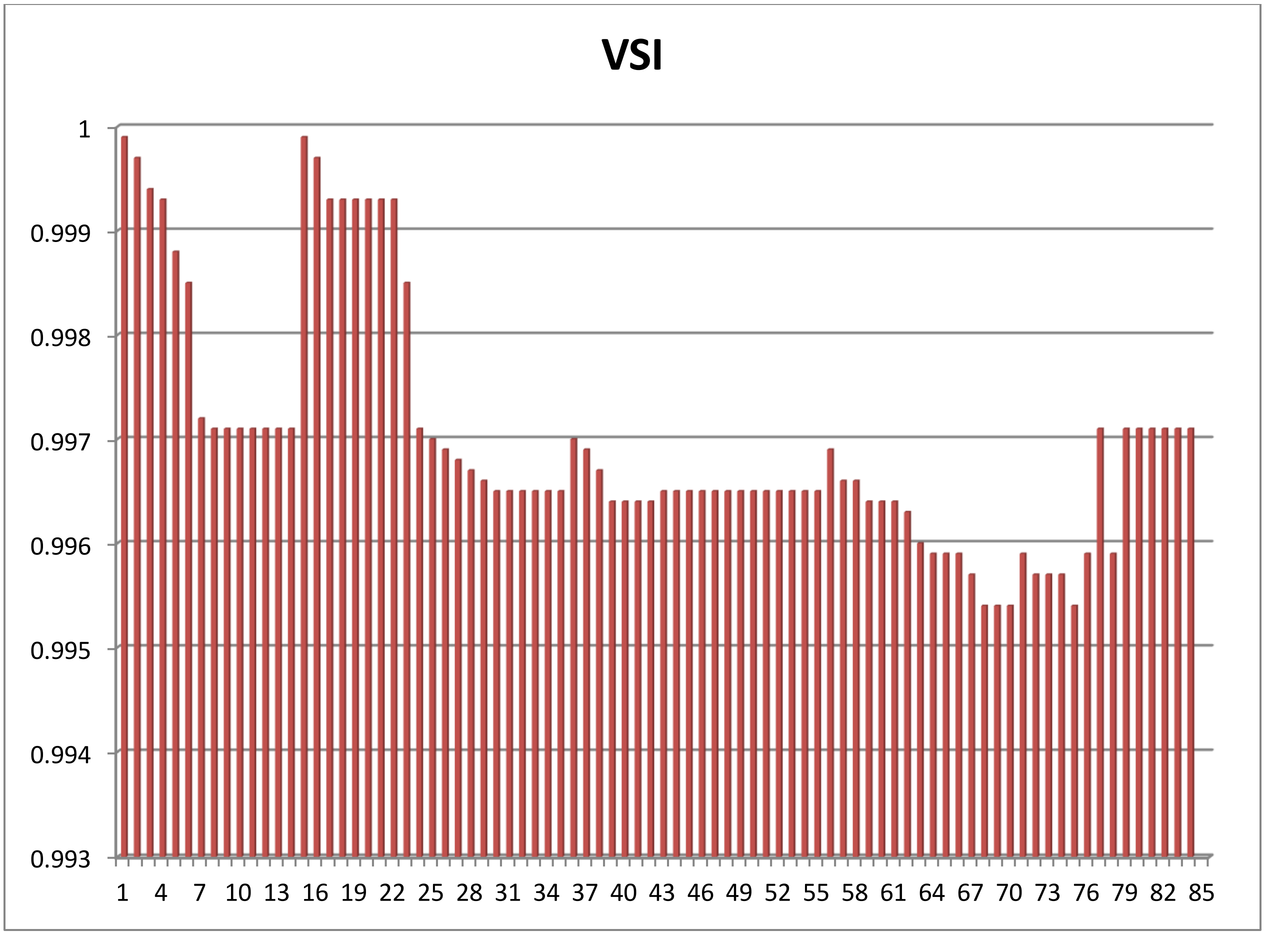

Figure 6.6: OPTIMISED VSI USINGHYBRID GA PSO FOR SYNCHRONOUS DG

Table 6.7: OPTIMIZATION RESULTS USING HYBRID GA PSO FOR SYNCHRONOUS DG

S. NO.	DG LOCATIONS	SIZE(MVA)	OBJECTIVE FUNCTION VALUE(f1,f2,f3)	COEFFICIENTS
1	13	1.7903+ J1.3121	0.65921	0.5
2	14	1.8465+ j1.5334	0.027186	0.4
3	25	0.3153+ j1.2524	1.007501	0.1

CHAPTER 7

CONCLUSION AND FUTURE SCOPE OF WORK

7.1 Comparison of algorithms for Unity Power Factor DG:

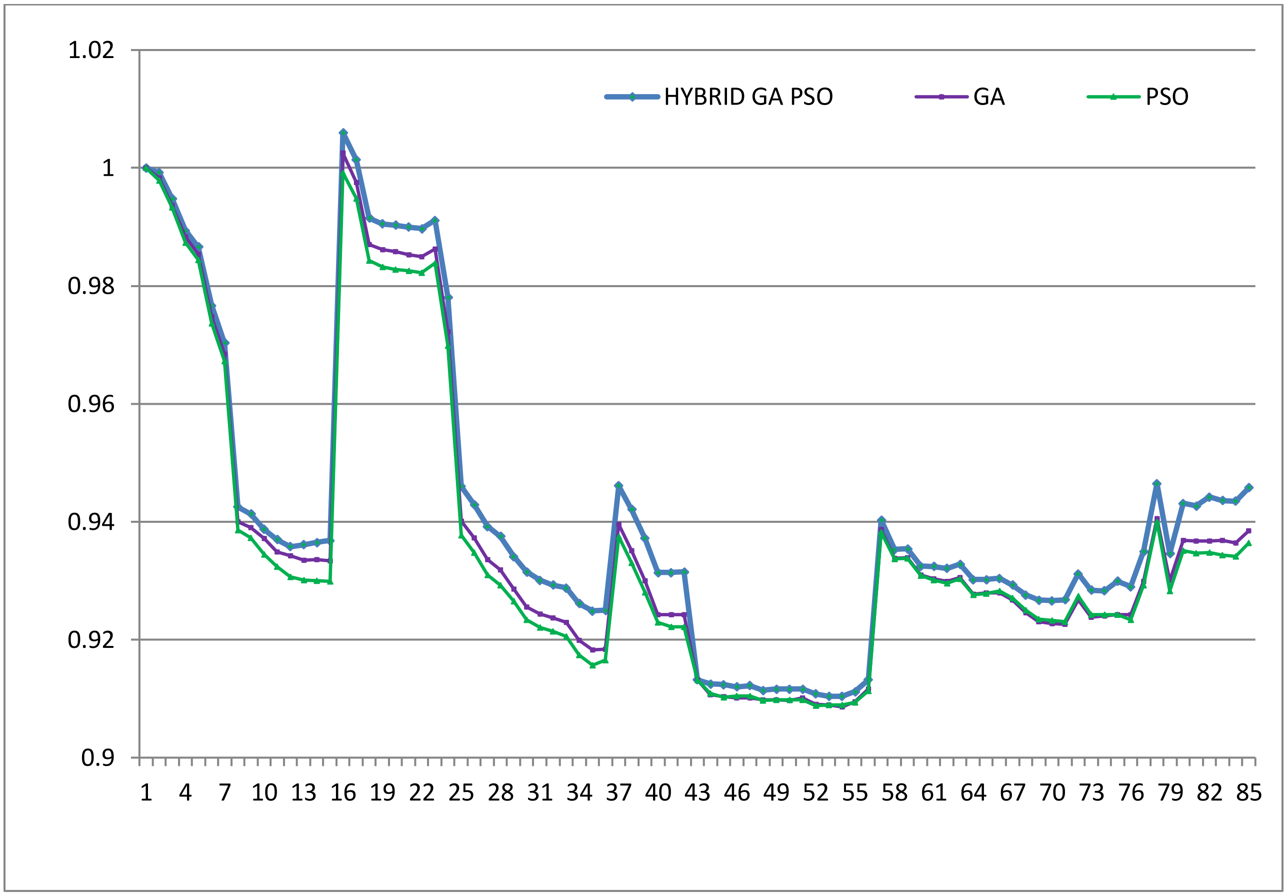

FIG 7.1: VOLTAGE PROFILE COMPARISON

Table 7.1: COMPARISON FOR UPF DG

Method	**Objective function value**				
	f1 value	f2 value	f3 value	Bus number	DG size(MW)
Hybrid GA PSO	0.44290	0.019305	1.005311	38 61 31	1.43143 1.425641 1.147537
GA	0.4333	0.08969	1.02502	47 29 45	1.7784 0.9660 1.1543
PSO	0.3964	0.023762	0.006541	13 77 27	1.364 1.1299 1.0111

7.2 Comparison of algorithms for Capacitor DG:

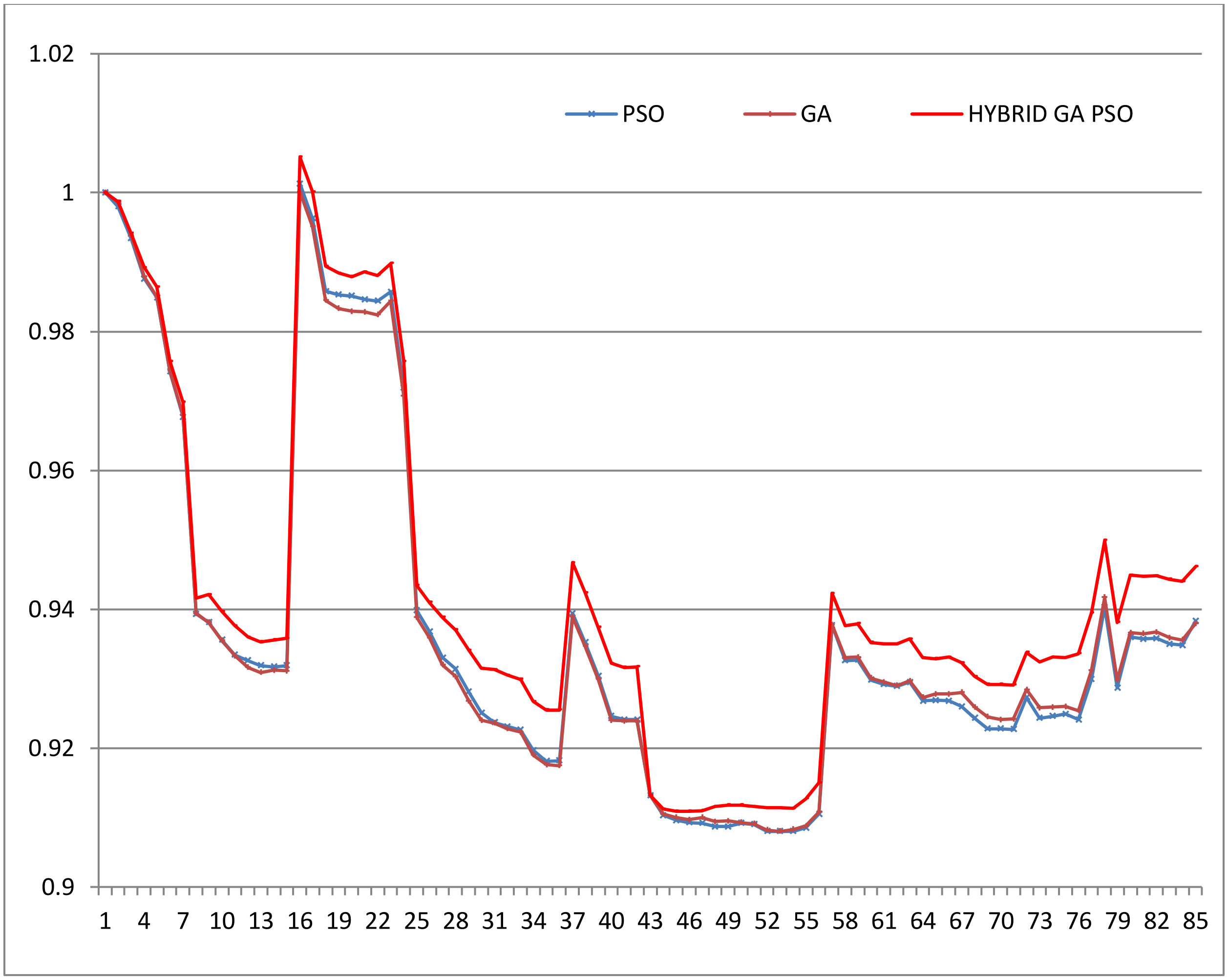

FIGURE 7.2: VOLTAGE PROFILE COMPARISON

Table 7.2: COMPARISON FOR CAPACITOR DG

Fig 7.4	**Objective function value**				
Method	f1 value	f2 value	f3 value	Bus number	DG size(MVA)
Hybrid GA PSO	0.161408	0.010845	1.002992	45 39 59	0.36724 0.45312 0.14762
GA	0.1599	0.02489	1.0718	44 64 67	0.20411 0.455023 0.35647
PSO	0.1756	0.0247	1.0068	54 50 26	0.1677 0.7334 0.4961

7.3 Comparison of algorithms for Synchronous DG:

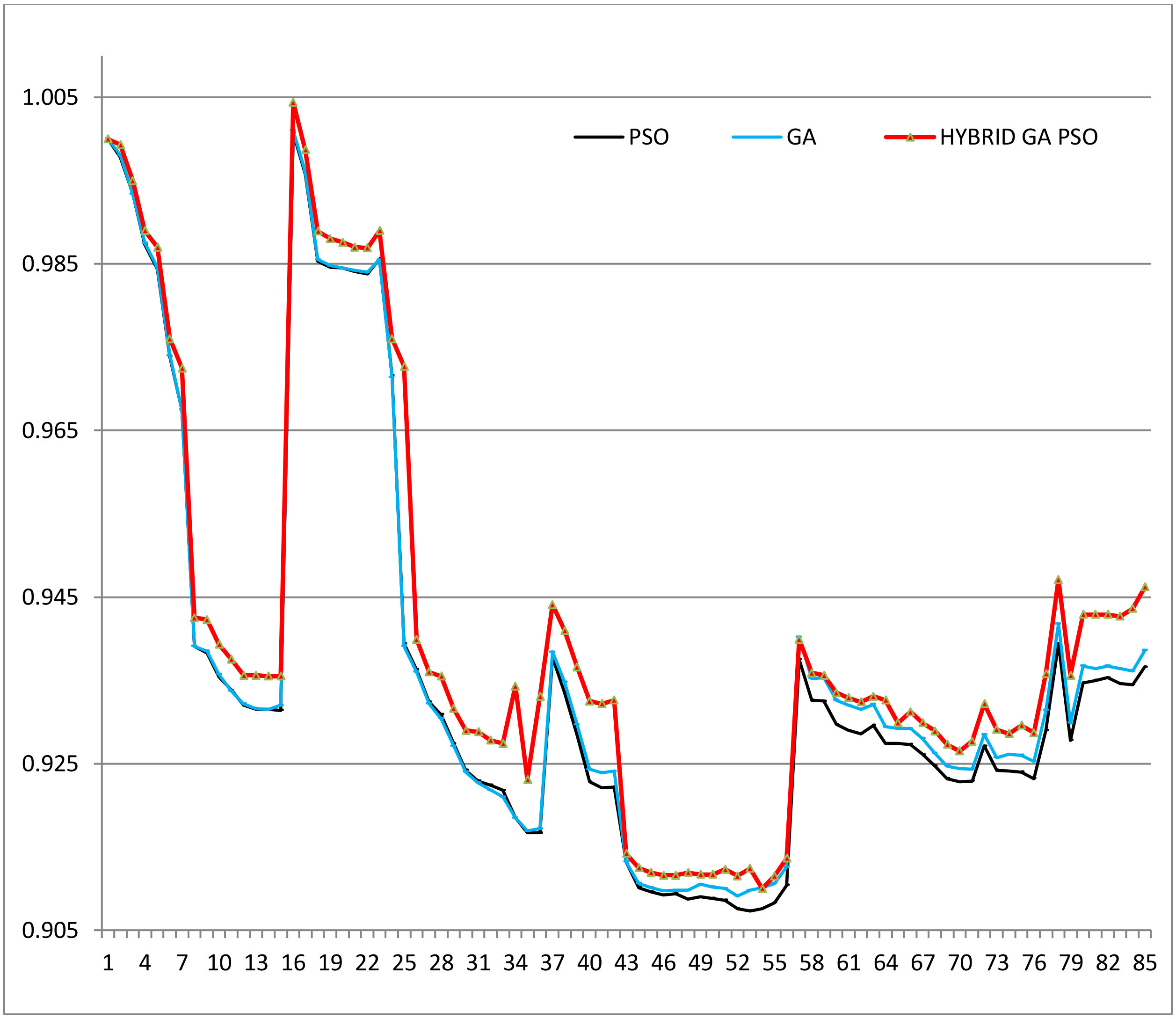

FIG 7.3: VOLTAGE PROFILE COMPARISON

TABLE 7.3: COMPARISON FOR SYNCHRONOUS DG

Method	**Objective function value**				
	f1 value	f2 value	f3 value	Bus number	DG size(MW)
Hybrid GA PSO	0.65921	0.02718	1.007501	13 14 25	1.7903+j1.3121 1.8465+j1.5334 1.3153+j1.2524
GA	0.2510	0.070014	1.019516	35 77 36	1.4761+j1.1191 0.9199+j0.6162 1.8013+j1.5165
PSO	0.55992	0.008146	1.002236	81 36 74	1.3425+j1.1225 1.9891+j1.9771 1.3425+j1.0313

7.4 CONCLUSION:

In capacitor DG by using GA power loss of the system is reduced 32.05% while using PSO 30.13%. But in hybrid GA PSO method the network losses reduced to 38.88%. In UPF DG by using GA line losses reduce to 140.01 KW (40.29%) and using PSO 147.59KW (37.05%). On the other hand by using hybrid technique the loss falls to 120.47 KW (48.3196%). In synchronous DG using GA network losses reduced to 122.92 KW (47.57%) and using PSO 125.87 (46.31%). But in case of hybrid technique losses reduced to 105.49 KW (55%).

In this chapter the comparison of the algorithms has been shown for various types of DGs. From the comparison shown in the figures it can be summarized that the incorporation of DG is profitable in the distribution system as it not only improves the power loss but also improves the voltage profile of the system. With the optimal location and sizing of the DG we can improve the voltage stability index. Hybrid method provides better improvement for the system stability, power loss and voltage profile when compared with genetic algorithm and particle swarm optimization for various types of DGs.

7.5 FUTURE SCOPE OF WORK:

Distributed generation is the idea to overcome the line losses while supplying expanding load demand in the distribution system thus study and analysis for further development and expansion of the idea is one of the prime research field of power system therefore future scope of work can be described as:

1.) Implementation of the variable load curve in load flow instead of constant power load with time.
2.) Study of distributed energy resources penetration level.
3.) Effect of DGs in power quality.
4.) Reconfiguration of the distribution system.

REFERENCES:

[1] R. E. Brown, electric power distribution reliability, CRC press, 2008. [Online].

[2] S.H. Horowitz, A.G. Phadke, Power System Relaying, 2nd Ed. Baldock: Research Studies Press Ltd, 2003. [Online].

[3] T. Ackermann, G. Andersson, and L. Sder, "Distributed generation: a definition," *Electric Power Systems Research*, vol. 57, pp. 195–204, 2001. [Online].

[4] P. S. Georgilakis and N. D. Hatziargyriou, "Optimal distributed generation placement in power distribution networks: models, methods, and future research," *IEEE Trans. Power Syst.*, 2013, 28, (3), pp. 3420–3428. [Online].

[5] Y. A. Katsigiannis and P. S. Georgilakis, "Effect of customer worth of interrupted supply on the optimal design of small isolated power systems with increased renewable energy penetration," *IET Gener. Transm. Distrib.*, 2013, 7, (3), pp. 265–275. [Online].

[6] Mohd Zamri Che Wanik, Istvan Erlich, and Azah Mohamed, "Intelligent Management of Distributed Generators Reactive Power for Loss Minimization and Voltage Control," *MELECON 2010 - 2010 15th IEEE Mediterranean Electro-technical Conference*, pp. 685-690, 2010. [Online].

[7] N.C. Sahoo, S. Ganguly, D. Das, "Recent advances on power distribution system planning: a state-of-the-art survey," *Energy Systems. 4* (2013) 165–193. [Online].

[8] A. Pecas Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, N. Jenkins, "Integrating distributed generation into electric power systems: a review of drivers, challenges and opportunities," *Electric Power Systems Research*, vol. 77, pp. 1189–1203, 2007. [Online].

[9] A. Keane *et al.* "State-of-the-Art Techniques and Challenges Ahead for Distributed Generation Planning and Optimization," *IEEE Trans. Power Systems*, vol. 28, no. 2, pp. 1493-1502, 2013. [Online].

[10] A. Alarcon-Rodriguez, G. Ault, S. Galloway, "Multi-objective planning of distributed energy resources: A review of the state-of-the-art," *Renewable and Sustainable Energy Reviews*, vol. 14, pp. 1353–1366, Renewable and Sustainable Energy Reviews 14 (2010) 1353–1366. [Online].

[11] D.Q. Hung, N. Mithulananthan, R.C. Bansal, "Analytical expressions for DG allocation in primary distribution networks," *IEEE Transactions on Energy Conversion*, vol. 25, no. 3, pp. 814-820, 2010. [Online].

[12] D. Das, “Reactive power compensation for radial distribution networks using genetic algorithm,” *International Journal of Electrical Power & Energy Systems,* Volume 24, Issue 7, pp. 573–581, October 2002. , [Online].

[13] A.M. El-Zonkoly, “Optimal placement of multi-distributed generation units including different load models using particle swarm optimisation,” *IET Gener. Trans. Distrib.*, vol. 5, no. 7, pp. 760–771, 2011. [Online].

[14] A.H. Mantway, M.M. Al-Muhaini, “Multi-objective BPSO algorithm for distribution system expansion planning including distributed generation,” *IEEE/PES Transmission and Distribution Conference and Exposition*, pp. 1–8, 2008. [Online].

[15] N.C. Sahoo, S. Ganguly, D. Das, “Simple heuristics-based selection of guides for multiobjective PSO with an application to electrical distribution system planning”, *Eng. Appl. Artif. Intell.* 24 (2011) 567–585. [Online].

[16] S. Ganguly, N.C. Sahoo, D. Das, “A novel multi-objective PSO for electrical distribution system planning incorporating distributed generation,” J. Energy Syst. 1 (2010) 291–337. [Online].

[17] M. A Kashem, Tas Hobart, A.D.T Le, M. Negnevitsky, G. Ledwich, “Distributed generation for minimization of power losses in distribution systems,” *Power Engineering Society General Meeting,* 2006. IEEE. [Online].

[18] S. Ghosh and D. Das, “Method for load-flow solution of radial distribution networks,” *IEEE Proceedings on Generation, Transmission & Distribution,* vol. 146, no. 6, pp. 641- 648, 1999. [Online].

[19] J. H. Teng, “A Direct Approach for Distribution System Load Flow Solutions,” *IEEE Transactions on Power Delivery,* vol. 18, no. 3, pp. 882-887, 2003. [Online].

[20] D. E. Goldberg, “Genetic Algorithm in search, optimization and machine learning,” 2002. [Online].

[21] S. Ganguly, N.C. Sahoo, D. Das, “Mono- and multi-objective planning of electrical distribution networks using particle swarm optimization,” Appl. Soft Computing. 11 (2011) 2391–2405. [Online].

[22] Zhipeng Liu, Fushuan Wen, and Gerard Ledwich, “Optimal Siting and Sizing of Distributed Generators in Distribution Systems Considering Uncertainties*,” IEEE Transactions on Power Delivery*, 26(2011) 2541-2551. [Online].

[23] M. H. Moradi, M. Abedin, ”A Combination of GA and PSO for Optimal DG Location and Sizing in Distribution System,” Electric Power and Energy Systems,34, (2012), 66-74.

[24] M. H. Moradi, M. Abedin,” A novel method for optimal DG units capacity and location in microgrids,” Electric Power and Energy Systems, 75, (2016), 236-244.

[25] S. K. Injeti, N. Prema Kumar,”A novel approach to identify optimal access point and capacity of multiple DGs in small, medium and large scale radial distribution systems, Electric Power and Energy Systems, 45, (2013), 142-151.

[26] A. A. Abou EL-Ela et al,”Maximal optimal benefits of distributed generation using genetic algorithms.” Electrical Power System Research, 80, (2010), 869-877.

[27] Satish Kansal, B.B.R. Sai, Barjeev Tyagi and Vishal Kumar, “Optimal placement of distributed generation in distribution networks,” *International Journal of Engineering, Science and Technology,* Vol. 3, No. 3, pp. 47-55, 2011. [Online].

[28] M.S. Kandil, M.M. El-Saadawi, A.E. Hassan, and K.M. Abo-Al-Ez, “A proposed reactive power controller for DG grid connected systems,” *Energy Conference and Exhibition (EnergyCon), 2010 IEEE International,* pp. 446 – 451, Dec 2010. [Online].

[29] D. Thukaram, H.P. Khincha and H.P. Vijaynarasimha, “Artificial Neural Network and Support Vector Machine Approach for Locating Faults in Radial Distribution Systems,” *IEEE Transactions on Power Delivery,* Volume: 20, Issue: 2, pp. 710 – 721, April 2000. [Online].

[30] M. E. Baran and F. F. Wu, "Optimal Capacitor Placement on Radial Distribution Systems," *IEEE PES winter meeting,* 1988. [Online].

[31] D. Das et al. “Simple and efficient method for load flow solution of radial distribution system” Electrical Power and Energy Systems, vol. 17, no. 5, pp. 335-346, 1995.

[32] A. Augugliaro et al., “A backward sweep method for power flow solution in distribution networks,” Electrical Power and Energy System, vol. 32, pp. 271-280, 2010.

[33] Eminoglu and Hocaoglu, “Distribution systems forward/backward sweep based power flow algorithms: A review andcomparison study,” *Electric Power Components and Systems,* vol. 37,pp. 91-110, 2009.

[34] Kersting, William. (2007). Distribution System Modeling and Analysis. 10.1201/9781420009255.book

[35] Tanveer Husain, Muqueem Khan, Mujtahid Ansari, “Power flow analysis of radial distribution system” IJAREEIE, vol. 5, 2016.

[36] Prem Prakash, D. K. Khatod,”Optimal sizing and siting techniques for distributed generation in distribution systems.” A Review, Renewable and Sustainable Energy Review, 57, (2016), 111-130.

[37] S. Bhullar and S. Ghosh,"Optimal integration of multi distribution generation sources in radial distribution networks using a hybrid algorithm," MDPI Journal, Energies 2018, 11, 628.

[38] Chidanandappa R. et al,"genetic algorithm based network reconfiguration in distribution systems with multiple DGs for time varying loads," Procedia Technology 21, (2015), 460-467.

[39] R. Viral and D. K. Khatod,"An analytical approach for sizing and siting of DGs in balanced radial distribution networks for loss minimization," Electric Power and Energy Systems 67, (2015), 191-201.

[40] V. Jagan Mohan and Albert,"Optimal sizing and siting of distributed generation using Particle Swarm Optimization guided Genetic Algorithm," Research India Publication, Advances in Computational research and Technology, ISSN 0973-6107, vol. 10, no. 5, (2017), p.p. 709-720.

APPENDIX

A.) BUS DATA FOR IEEE 85 BUS :

NODE NO.	NODE CODE	VOLTAGE MAGNITUDE	ANGLE	LOAD (KW)	LOAD (KVAR)
1	1	1	0	0	0
2	0	1	0	0	0
3	0	1	0	0	0
4	0	1	0	56	57.13
5	0	1	0	0	0
6	0	1	0	35.28	36
7	0	1	0	0	0
8	0	1	0	35.28	36
9	0	1	0	0	0
10	0	1	0	0	0
11	0	1	0	56	57.13
12	0	1	0	0	0
13	0	1	0	0	0
14	0	1	0	35.28	36
15	0	1	0	35.28	36
16	0	1	0	35.28	36
17	0	1	0	112	114.26
18	0	1	0	56	57.13
19	0	1	0	56	57.13
20	0	1	0	35.28	36
21	0	1	0	35.28	36
22	0	1	0	35.28	36
23	0	1	0	56	57.13
24	0	1	0	35.28	36
25	0	1	0	35.28	36
26	0	1	0	56	57.13
27	0	1	0	0	0

28	0	1	0	56	57.13
29	0	1	0	0	0
30	0	1	0	35.28	36
31	0	1	0	35.28	36
32	0	1	0	0	0
33	0	1	0	14	14.28
34	0	1	0	19.5	19.89
35	0	1	0	0	0
36	0	1	0	35.28	36
37	0	1	0	56	57.13
38	0	1	0	56	57.13
39	0	1	0	56	57.13
40	0	1	0	35.28	36
41	0	1	0	0	0
42	0	1	0	35.28	36
43	0	1	0	35.28	36
44	0	1	0	35.28	36
45	0	1	0	35.28	36
46	0	1	0	35.28	36
47	0	1	0	14	14.28
48	0	1	0	0	0
49	0	1	0	0	0
50	0	1	0	36.28	37.01
51	0	1	0	56	57.13
52	0	1	0	0	0
53	0	1	0	35.28	36
54	0	1	0	56	57.13
55	0	1	0	56	7.2
56	0	1	0	14	14.28
57	0	1	0	56	57.13
58	0	1	0	0	0
59	0	1	0	56	57.13

60	0	1	0	56	57.13
61	0	1	0	56	57.13
62	0	1	0	56	57.13
63	0	1	0	14	14.28
64	0	1	0	0	0
65	0	1	0	0	0
66	0	1	0	56	57.13
67	0	1	0	0	0
68	0	1	0	0	0
69	0	1	0	56	57.13
70	0	1	0	0	0
71	0	1	0	35.28	36
72	0	1	0	56	57.13
73	0	1	0	0	0
74	0	1	0	56	57.13
75	0	1	0	35.28	36
76	0	1	0	56	57.13
77	0	1	0	14	14.28
78	0	1	0	56	57.13
79	0	1	0	35.28	36
80	0	1	0	56	57.13
81	0	1	0	0	0
82	0	1	0	56	57.13
83	0	1	0	35.28	36
84	0	1	0	14	114.28
85	0	1	0	35.28	36

B.) BRANCH DATA FOR IEEE 85 BUS SYSTEM :

BRANCH NO.	From	To	R	X
1	1	2	0.108	0.075
2	2	3	0.163	0.112
3	3	4	0.217	0.149
4	4	5	0.108	0.074
5	5	6	0.435	0.298
6	6	7	0.272	0.186
7	7	8	1.197	0.82
8	8	9	0.108	0.074
9	9	10	0.598	0.41
10	10	11	0.544	0.373
11	11	12	0.544	0.373
12	12	13	0.598	0.41
13	13	14	0.272	0.186
14	14	15	0.326	0.223
15	2	16	0.728	0.302
16	3	17	0.455	0.189
17	5	18	0.82	0.34
18	18	19	0.637	0.264
19	19	20	0.455	0.189
20	20	21	0.819	0.34
21	21	22	1.548	0.642
22	19	23	0.182	0.075
23	7	24	0.91	0.378
24	8	25	0.455	0.189
25	25	26	0.364	0.151
26	26	27	0.546	0.226
27	27	28	0.273	0.113
28	28	29	0.546	0.226
29	29	30	0.546	0.226
30	30	31	0.273	0.113
31	31	32	0.182	0.075
32	32	33	0.182	0.075
33	33	34	0.819	0.34
34	34	35	0.637	0.264
35	35	36	0.182	0.075
36	26	37	0.364	0.151
37	27	38	1.002	0.416

38	29	39	0.546	0.226
39	32	40	0.455	0.189
40	40	41	1.002	0.416
41	41	42	0.273	0.113
42	41	43	0.455	0.189
43	34	44	1.002	0.416
44	44	45	0.911	0.378
45	45	46	0.911	0.378
46	46	47	0.546	0.226
47	35	48	0.637	0.264
48	48	49	0.182	0.075
49	49	50	0.364	0.151
50	50	51	0.455	0.189
51	48	52	1.366	0.567
52	52	53	0.455	0.189
53	53	54	0.546	0.226
54	52	55	0.546	0.226
55	49	56	0.546	0.226
56	9	57	0.273	0.113
57	57	58	0.819	0.34
58	58	59	0.182	0.075
59	58	60	0.546	0.226
60	60	61	0.728	0.302
61	61	62	1.002	0.415
62	60	63	0.182	0.075
63	63	64	0.728	0.302
64	64	65	0.182	0.075
65	65	66	0.182	0.075
66	64	67	0.455	0.189
67	67	68	0.91	0.378
68	68	69	1.092	0.453
69	69	70	0.455	0.189
70	70	71	0.546	0.226
71	67	72	0.182	0.075
72	68	73	1.184	0.491
73	73	74	0.273	0.113
74	73	75	1.002	0.416
75	70	76	0.546	0.226
76	65	77	0.091	0.037
77	10	78	0.637	0.264
78	67	79	0.546	0.226

79	12	80	0.728	0.302
80	80	81	0.364	0.151
81	81	82	0.091	0.037
82	81	83	1.092	0.453
83	83	84	1.002	0.416
84	13	85	0.819	0.34