Feasibility Study of location of Photovoltaic System in Patiala Distribution Network.

A dissertation submitted in fulfillment of the requirements for the degree of

Master of Engineering

in

Power Systems

Submitted By

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2017

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CERTIFICATE

I hereby certify that this thesis entitled, **"Feasibility Study of location of Photovoltaic System in Patiala Distribution Network"** in fulfillment for the requirements for the award of degree of **Master of Engineering (Power systems)** submitted to Electrical and Instrumentation Engineering Department, Thapar University, Patiala, is an authentic record of my own work and is carried under the supervision of **Dr. Shakti Singh**. The matter submitted via this thesis report has not been submitted for the award of any other degree to the best of our knowledge.

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

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ACKNOWLEDGEMENT

First and foremost, praises and thanks to the God, the Almighty, for his showers of blessings throughout my research work to complete the research successfully.

I wish to express my sincere gratitude to Dr. Shakti Singh, Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, for his valuable guidance, support and for sharing his pearls of wisdom with me throughout my M.E.. Working under your supervision had enlightened me and helped me to grow in all the areas of the study. The fruitful discussions with him throughout the research work were a great help for the successful completion of the present work.

I also wish to thank Dr. Mukesh Singh, Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, for his constant support and guidance throughout my experimental work on the DIgSilent: Power factory software. I thank him for believing in me and guiding me in carrying out all the experiments for my research work.

I would also like to express my gratitude to the entire Electrical and Instrumentation Engineering Department for providing me every help in carrying out my research work.

Last but not the least, I am thankful to my parents, friends, and colleagues for their constant encouragement and support in building up my thesis report.

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LIST OF ABBREVIATIONS

LV	Low voltage
PV	Photovoltaic
DSTATCOM	Distributed static compensator
EV	Electric vehicle
DG	Distributive generation
RES	Renewable energy source
FACT	Flexible AC transmission
P	Active power flowing in circuit.
Q	Reactive power
E	Sending end voltage
V	Receiving end voltage
Z_{line}	Impedance of line carrying power
P_{PL}	Power output from solar PV
P_L	Power required by load
P_{grid}	Power received from grid
P_{Rat}	Rated output of PV system
α	Temperature coefficient of power
f_{loss}	Loss factor due to dirt
G_s	Standard incident radiation
G_h	Hourly solar radiation
T_C	Temperature in current time step
T_s	Temperature under standard conditions

ABSTRACT

Voltage and frequency regulation by synchronizing control devices is the most challenging aspect for an active electricity network. Electric companies are searching new remedies to square off this challenging problem. It is a major impact can be observed on low voltage power system. Hence picking the consumer at low voltage is main concern, there must be no or least variation in distribution end voltage and frequency. The present study provides an adaptive and portable methodology which aims at minimizing distribution end voltage variation. Being renewable and environmental friendly, photovoltaic power injection can be used as a remedy to regulate consumer end voltage. PV power injection technology could be used by electric companies in future as a replacement of the expanding network. In the present study, a real time distribution system suffering from voltage regulation problem is taken into consideration. Detection of location for PV power system and the respective power ratings are estimated on the basis of their results. Also, change in line losses due to redistribution of power from substation to load are also taken care. Overall, PV power injection methodology has been proved to be a cost effective method. Recent survey for the system is performed by calculating the load flow to obtain the voltage at each and every consumption point. Simulation is performed by using DIgSILENT power factory software. Results are concluded on the basis load flow report generated and specifies the number of nodes that are suffering from voltage instability. Ratings of PV power injection are also decided by these results only.

Keywords: DIgSILENT power factory software, Distributed generation (DG), Flexible AC transmission (FACTS), Photovoltaic (PV) power, Renewable energy resources (RES) and Voltage regulation (VR).

Chapter 1

INTRODUCTION

1.1 Overview

Stability of power system is a primary constituent to be maintained with constantly increasing load. Function of power system is to deliver the power from generator to consumer. It is mainly classified into three parts viz., generation, transmission and distribution system. As large number of LV loads are connected to the distribution system, it requires special attention to voltage and frequency variations [1]. Regulation of voltage and frequency should be in permissible or predefined range causing no harm to the existing connected load [2], [3]. Deviation in voltage depends upon the reactive power and the frequency change is related with active power demand of load. That means voltage as well as frequency regulation both depends up on load changes. Electric load increases with increase in number of consumers. As the number of consumers in a group or a system increases, the contribution of a single consumer over large fluctuations decreases. Voltage variation with load is accounted in this study. Increasing load demand is the primary factor that needs to be accounted for uncontrollable voltage. By perceptive present load curve, it can be estimated that demand gets doubled or tripled in the next 5-7 years. Varying power demand can either be fulfilled by interconnection of power system or by using localized power sources. However, the transmission and distribution infrastructures cant be altered frequently. Therefore, a solution of this problem should be found in such a way that it can handle future loading problems without expansion of network. Moreover, techniques already implemented and should be implemented according to the consumers end demand [4].

Maintaining stable voltage throughout the day is a difficult task to deal with, due to the existing transmission and distribution system. Changing load is one of the cause for voltage instability. There is direct relation between the load and voltage stability, that is why voltage stability is also known as load stability. Moreover, voltage instability limits the power transfer through the lines. Another main reasons for voltage variation in system is faulty condition [4]. Due to instantaneous fault, large disturbances occurs in systems. In present study smart grid technology deals with problem of voltage instability. This technology has a potential to cause a great improvement in the enactment of the electrically powered system. It also offers the similar enactment as the prevailing technologies in a more economical and consistent way [5]. Voltage stability is defined as capability of control systems to preserve stable voltages at numerous buses even after exposure to a disruption from specific predefined point [4]. With gradual or steady load variation, voltage stability of system gets affected [5].

To resolve the voltage regulation problem,market interconnection or enlargement of system could be a probable solution. However, this will incorporate manageable resources resulting in the complexity and cost inefficiency of the system. Therefore, while dealing with voltage regulation in the distribution part of the electrical system, it is necessary to understand about the voltage variation and its remedies [6]. Voltage variation generally means change the RMS value of the voltage. Voltage variation is further classified as short term and long term depending upon the time of occurrence [7]. As already discussed that instability in voltage is either caused by internal faults or a large load changing. For detection of internal faults, proper protecting systems are installed. Moreover, for changing the load characteristics, Distributed Generation (DG) method can be used. DG is medium or small size electrical source installed near load centers [8]. Here, described methodology enhances the use of renewable energy source (RES), specifically Photovoltaic (PV) cell has been used to control the voltage variations [9]. PV injection power ratings and locations are decided by observing the voltage behavior after simulation results. The PV power installation can be a useful suggestion for future overloading problems [10].

1.2 Literature survey

The PV power system is the fastest growing system among all the available renewable energy sources [11]. Specifically, the trend of grid connected PV plants are incorporated near distribution substations is rising. The rating of these PV plants may vary from 10 kW to 10 MW [7]. These are a substitute for the conventional electrical energy sources and can be used for solving humanity energy dilemma. Moreover, PV power injection systems account for the low running cost, therefore it indicates its more advantageous use in the distribution system of the developing countries [12]. Varying load demand of system can be selected as installation of more PV is not baffling [13].

PV power injection has a distinct control feature that unambiguously provides for the high ramp-rate deviations of PV output thus supporting the purposes comprising voltage fluctuation modifications. This makes PV power injection system more preferable over other methods [14].

The problem of voltage regulation can also be resolved by using tap changing transformer, Flexible AC Transmission (FACT) based tools that can be used for both transmission and distribution, distributed generation or by using Electrical Vehicle (EV) technology method. DG power source specifically PV power injection method is cost efficient method as compared to the other methods. Tap changing transformers are simple but its installation and maintenance is high-priced [15]. However, FACTS devices can be used either in transmission or distribution to regulate consumer end voltage. FACTS devices are classified according to their applications i.e. their power rating depends on whether they are used in transmission or distribution [16]. Moreover, they are defensive devices and require vigilance as power electronics switches are involved. Mostly present-day utilized technique of charging and discharging in an EV for voltage regulation. However, this technique needs a complex setup and highly trained engineer resulting into high amount of investment. On the another side, DG power source is renewable energy source, which is much cheaper and efficient method. This is the reason that solar photovoltaic is the fastest growing system among all the RES in the world, with annual growth rates of about 30% over the last decade [17].

The use of tap changing transformer method among all other methods, is avoided due to its low efficiency [18, 19]. However, now-a-days distribution system compatible with FACT devices (specially distributed static compensator) which could control the flow of active and reactive power and extensively used. Flexible AC transmission devices are efficient and adoptable for voltage regulation. On the other hand, voltage regulation using EV is still a growing method in regulation field. Moreover, many charging station are to be established at different location to use this technique. Presently, this method has not been widely used [20].

Solar PV power injection is a renewable distributed energy source used at non-identical locations [17]. Instead of using solar power, wind power can also be injected. Moreover, site selection for establishment of wind farm is a difficult task as it requires large area where wind flows with constant speed throughout the year. However, solar PV plant can be established on roof top area of distribution substation [21]. Above all methods like wise use of dynamic voltage resistors, tap changing transformers or FACT devices are mainly used to minimize the effect of voltage variations on distribution side [18, 19]. In the present study the facilitation of distributed generation power in distribution network is discussed. This helps in maintaining of the level of voltage reduced during transmission. Moreover, reference is taken from the distribution area of Patiala grid for modeling [22].

By the end of 2017, PV generation electrical capacity is expected to reach 200 GW [23]. PV systems are generally incorporated at the Medium Voltage (MV) and Low Voltage (LV) distribution system. According to other researches, rating and location of PV power placement is calculated by two mathematical techniques [23, 24]. For more precise voltage control On Load Tap Changing (OLTC) transformer and Voltage Regulating (VR) devices are used along with PV systems. Also, it is affiliated with PV power injection in transmission system [24].

1.3 Motivation of the work

Various researchers have suggested different methods to restore voltage after assorted instability strokes [25]. Among all technologies used, most appropriate method found is PV power injection [26]. PV system is environmental friendly power source which makes it to grow faster than other sources. Also, aim of voltage regulation at load end is successfully accomplished by this sustainable energy source. Presently, this methodology is deliberated by simulating a particular area from the distribution network of Patiala city. Results with for-casted load is used by concerned public authorities for future voltage regulation problems. Also, same work is performed by with mathematical calculation of load flow analysis where as this dissertation suggested a analytical method for same the problem [23]. Here, location and amount of power injection is calculated by simulation using new software named as “DIgSILENT: power factory” [27]. Calculated results are feasible and realistic to implement [28].

1.4 Contribution to the work

The major contribution of this dissertation is summarized as follows:-

- PV power injection method (being economic and environmental friendly) has been used for voltage regulation of the complex distribution system of Patiala city.
- The results obtained can be helpful for concern public authorities in future for

voltage regulation problem.

- Location and amount of power injected in the distribution system has been obtained through simulation on DIgSILENT power factory software.
- It is a mobile power source which can be transported easily from one place to other.

1.5 Organization of the dissertation

The work of dissertation is divided into 5 chapters.
Chapter 1 gives a brief introduction, literature review and motivation for control problem.
Chapter 2 deals with basics of voltage types of voltage stability. Also, deals with different methods to increase stability of system.
Chapter 3 foreground with system modeling and adopted methodology.
Chapter 4 deals with discussions of the results for two separate sections under Patiala grid.
Chapter 5 concludes the dissertation with future scope of PV power in power system.

Chapter 2

VOLTAGE STABILITY

2.1 Voltage stability

Voltage stability is an ability of power system to maintain equilibrium voltages at all feeders and buses after the occurrence of small or large disturbances. The system enters in the voltage instability domain when an external, internal disturbances or an increase in load demand results in an continuous and unmanageable drop in bus voltage [29]. System is said to be perfectly stable for an operating point if voltage at any bus increases with increase in reactive power supply at same bus. Whereas, reduction in bus voltage occurs with increase in reactive power injection at the same bus, this leads to system instability [30]. With respect to the stability, load and load characteristics plays an important role. Moreover with increase in load stress, their is increase in reactive power demand which inherently further reduces system voltage.

Fig 2.1 shows the classification of stability in power system.

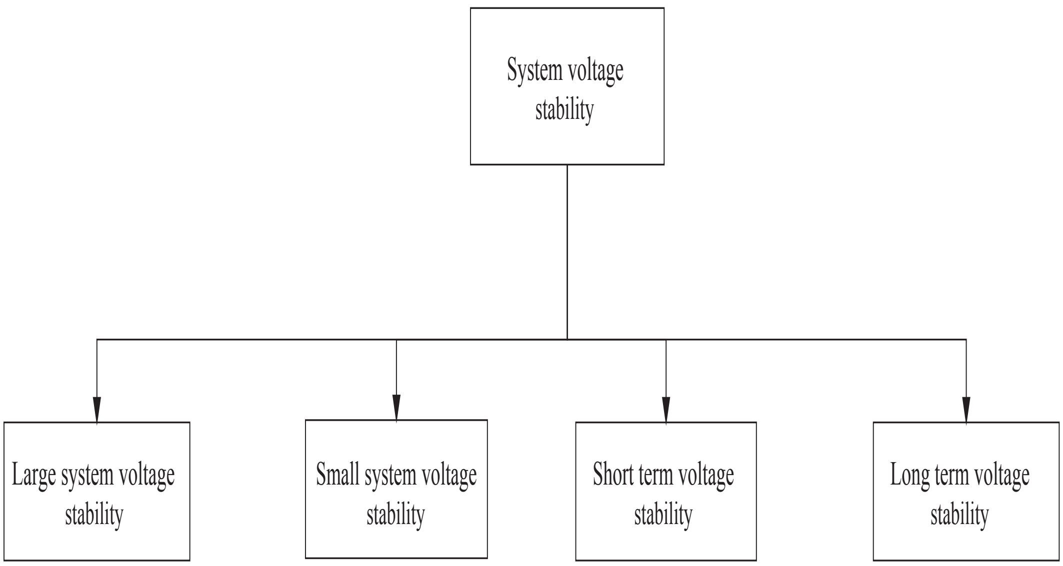

Fig. 2.1: Classification of stability.

Voltage stability is mainly classified in four categories:

- **Large disturbance voltage stability**:- It is the ability of system equilibrium voltage followed by large disturbances like system faults or loss of generation. Study time to be considered is from few seconds to few minutes.
- **Small disturbance voltage stability**:- It is the ability of system to maintain stability during small perturbations such as increment or decrement change in load.
- **Short term voltage stability**:- It is the stability, involving fast acting load components such as electronically controlled loads, induction motors and HVDC converters. Analysis time required for differential calculations is few second to few minutes.
- **Long term voltage stability**:- It involves dynamics of slower acting loads like thermostatically controlled loads, tap changing transformer and generator current limiters. It require long term dynamics simulation for analysis. Fig 2.2 shows flow of power from generator to load side.

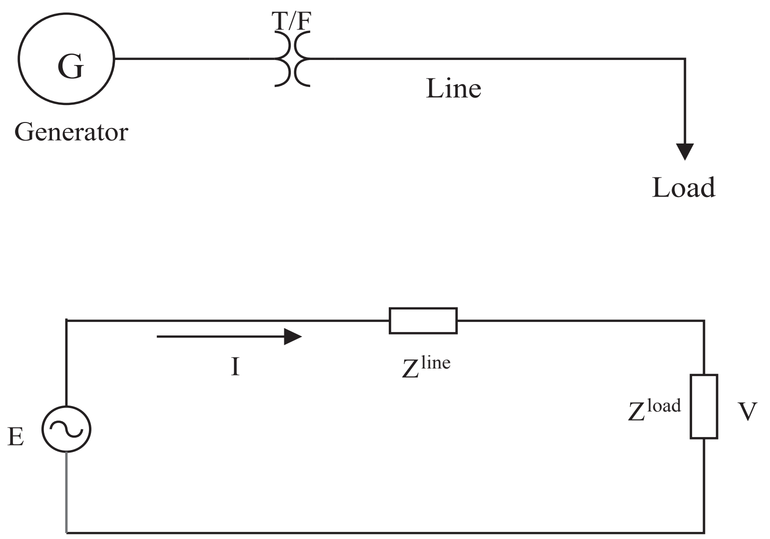

Fig. 2.2: Simple radial power system.

In modern scenario, due to exponential increase in load demand, power crises are increasing. Since, load is purely unpredictable and varies hour by hour, day by day and weather to weather. Also, loads are further classified as resistive, inductive and capacitive loads. Most of the loads are lagging in nature. Power system parameter like wise voltage and frequency are getting affected due to these crises conditions [31]. Exact estimation of load is not possible. Therefore, approximate load curve is plotted on the basis of daily load curve study. Customer end equipments are highly affected by these parameter variations as life cycle of equipment is reduced. Other than load factor there are many other factors does exist which are responsible for causing instability or unpredictable changes in voltage and frequency.

However, methodology described below deals with change in voltage parameter specifically at distribution end. Power framework supplies energy to countless loads and is sustaining from many producing units. In this manner, there is an issue of keeping up voltages inside required breaking points. Voltage changes mainly occurs due to the following reasons:

- Nature of load and load switching.
- Switching operation of compensation devices.
- Faults in either transmission or distribution line.
- Transmission and distribution line configurations.
- External interference.

Also, magnitude of voltage depends on reactive power flow in network. Excess consumption of reactive power at any particular point can result into decrease in voltage magnitude at that particular point. Since the receptive power can't be exchanged or transported over long separations as voltage regulation has to be effected by using unique devices which are located in the distribution network. These devices usually helps in keeping decent magnitude of voltage in the power network. There have been used practically since the first power systems invented. Expanding necessities in regards to both the supply unwavering quality and nature of provided power compel utilizing more current (quicker, more solid, with a more extensive scope of uses) gadgets. The correct determination and coordination of hardware for controlling responsive power and voltage security are among the significant difficulties of energy framework designing [32]. These difficulties brought forth some chose devices to control or repay responsive power. Devices are named as follows:

- Dynamic voltage resistors.
- Isolating transformers.

- Tap changing transforms.
- Isolating transformer.
- Distributed Static Compensator (DSTATCOM).
- Use of electric vehicle.

These devices are conventionally used as they are having low efficiency. However, DSTATCOM is used widely these days.

Compared to all, DG is found to be most efficient method as it is based on renewable energy resources like photovoltaic cells based on solar power and wind power generation based on wind velocity.

2.2 Distributed generation

As moving in accordance with present scenario when all non renewable energy resources are depleting, DG can be proved as environmental friendly and reliable energy source. They can be defined as specific small generators supported by renewable resources as input power. It can also be defined as,

- IEEE defines the generation of electricity by facilities sufficiently smaller than central plants, usually 10 MW or less, so as to allow interconnection at nearly any point in the power system, as distributed resources.
- Electric Power Research Institute (EPRI) defines distributed generation as generation from a few kilowatts up to 50 MW.
- International Energy Agency (IEA) defines DG as, "Power generation equipment and system used generally at distribution levels and where the power is mainly used locally on site".
- The International Council on Large Electricity Systems (CIGRE) defines DG as generation that is not centrally planned, centrally dispatched at present, usually connected to the distribution network, and smaller than 50-100 MW.

There are many reasons a client may introduce a disseminated generator [33]. DG can be utilized to produce a client's whole power supply, creating a bit of a client's power nearby to lessen the measure of power acquired amid pinnacle cost periods, for standby or crisis era (as a reinforcement to Wires Owner's energy supply), as a green power source (utilizing inexhaustible innovation), or for expanded unwavering quality [34]. In some remote areas, DG can be less exorbitant as it kills the requirement for costly development of circulation and additionally transmission lines [35]. Fig 2.3 depicts operation of DG in power systems.

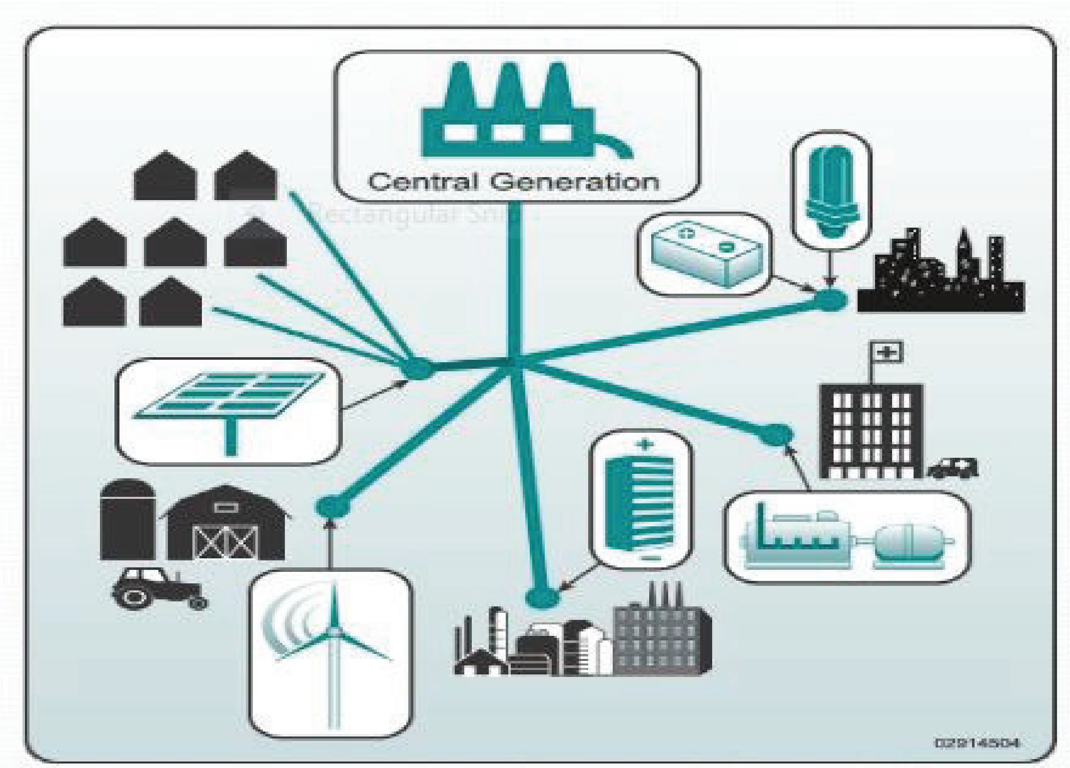

Fig. 2.3: Distributed power generation [36].

2.2.1 Advantages of distributed generation

1. It has a lower capital cost because of the small size of the DG (although the investment cost per kVA of a DG can be much higher than that of a large power plant).

2. They can be located near load points. Therefore, losses during transmission of power are nearly equal to zero.

3. They have reduces load on main grid as it provides power locally to consumer.

4. Also, produces zero or near-zero pollutant emissions over its useful life (pollutant emissions is not taking into consideration over the entire product life cycle i.e. pollution produced during the manufacturing).

5. It can be combined with some technologies such as solar or wind to form of renewable energy.

6. It can increase power reliability as back-up or stand-by power to customers.

2.2.2 Recent development in the field of PV system

The Government of India established an organization 20^{th} September, 2011 named as Solar Energy Cooperation of India (SECI). It is a non profitable organization which manages all the solar projects all over India. Also, plan and execute an integrated program on development and deployment of solar energy technologies to achieve commercialization.

As part of the mission activities SECI has taken up the following projects.

- Solar thermal installations for water/air heating.
- Implementation of solar roof-top scheme.
- Development and dissemination of low cost solar lanterns.
- Grid connected solar power plants.
- Solar mini/ micro grids.

National Institute of Solar Energy (NISE) is the another autonomous institution of Ministry of New and Renewable (MNRE) which is established to promote the use of solar power in India. The Government of India established this institute in Sep, 2013 on Gurgaon-Faridabad road, to assist the ministry in implementing the national solar mission and to coordinate research, technology and other related works. The association is active in demonstration, interactive research, training and testing solar technologies and systems.

This institute is established with a mission i.e., establish itself by 2030 as one of the leading institutes in the field of solar energy by research, testing and policy planning of solar energy related matters. Also, as a school for development of human resources, offering training and other services at various levels by adopting latest techniques in the area of engineering and science related to applications of solar energy.

Chapter 3

ADOPTED METHODOLOGY

3.1 Introduction

Presently, crises of power is biggest problem faced by world. For a comfortable survival, mankind has to adopt different methodologies. In order to over come this shortage and instability of different parameters in power system. Here, the most concerned parameters are voltage and frequency variation. Moreover, voltage variation is a big issue in power system particularly distribution end voltage. This dissertation introduces a methodology of DG i.e. using photovoltaic power generation method which helps in stabilizing the distribution side voltage. The concept of introducing DG reduces the dependency on main grid. However, DG's are small power generators that can be placed any where in power system. Moreover, different locations in distribution network are selected to place PV panels according to there individual panel capacities. Also, according to the load stresses and solar pattern these energy sources respond toward the voltage and frequency variations. Proper synchronization and controlling are required between solar panels and distribution grid. The aim of this dissertation is to evaluate the effect of distributed voltage on the different buses mathematically. In this chapter, the technique for improving voltage profile for a particular affected area. The surroundings and methodology of power injection is explained in section I and section II respectively.

3.2 System modeling

This section describes, a target section of LV distribution system network is used for case study. A LV distribution feeder system along with High Voltage (HV) integrated substation system is modeled. So that the possible DG could be placed as voltage regulating device using the concept of simultaneous and non-simultaneous responses of the DG units. Distribution system of a congested city is very complex to simulate, therefore distribution model is divided into different HV substation areas. Here, instead of taking entire Patiala city, a 220 kV substation is modeled. Fig. 3.1 represents line diagram of substation and different areas connected to it.

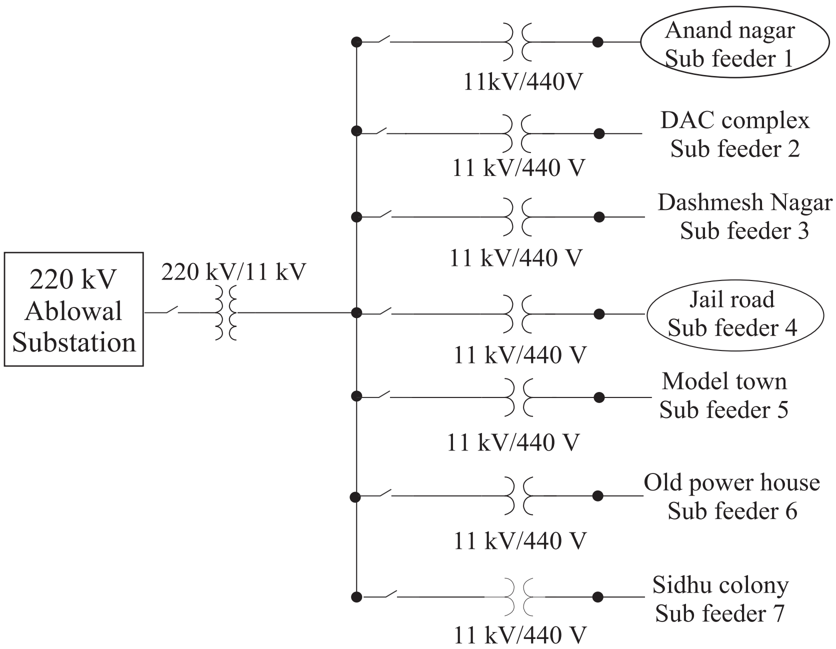

Fig. 3.1: Line diagram of distribution system with encircled target area.

Active and reactive power reaches to load through this network. Deficiency of reactive power results in instability of voltage. Flow of power depends on magnitude of load voltage as shown in following expressions.

$$P = \frac{V_i V_o sin\theta}{Z} \tag{3.1}$$

$$Q = \left[\frac{V_i V_o cos\theta}{Z}\right] - \left[\frac{V_o^2}{Z}\right] \tag{3.2}$$

Where P and Q are active and reactive powers respectively. V_i and V_o are generating end and load end voltages respectively. Whereas, θ represents phase angle difference between sending and receiving end voltage. Z represents line impedance [37].

$$P = \left[\frac{V_o}{V_{on}}\right]^a * P_n \tag{3.3}$$

$$Q = \left[\frac{V_o}{V_{on}}\right]^b * Q_n \tag{3.4}$$

Where, n stands for nominal values and values for a lies in the range 0.6 to 1.4 and b in 1.5 to 3.2. Average values of these exponents are 1 and 2 respectively. These relations are showing power dependency on voltage. All the above equations are showing relationship between power and voltage. Their inherent deficiency of reactive power supply causes voltage instability and vice versa, immense network with large number of consumers are consider. Here, by injecting small amount of power from different locations in this system, voltage profile is improved. This localize power generation is known as distributed generation.

3.2.1 DG in LV distribution systems

A large number of DG embedded in LV distribution systems are typically based on renewable technology resources. These DG units can be operated in voltage control mode by injecting power proportional to instantaneous load variation. The regulator circuit is normally equipped with over and under excitation limiters. These exciter works according to the play script of load side voltage and output of generator's reactive power capability of the DG unit. As a result, the DG active power may also to be controlled, if the DG unit needs to be operated for network Volt/ VAr support under all system conditions. Therefore, using DG units, voltage profile of system can be improved. For this DG rating and location estimation should be performed on the results of load flow generated report.

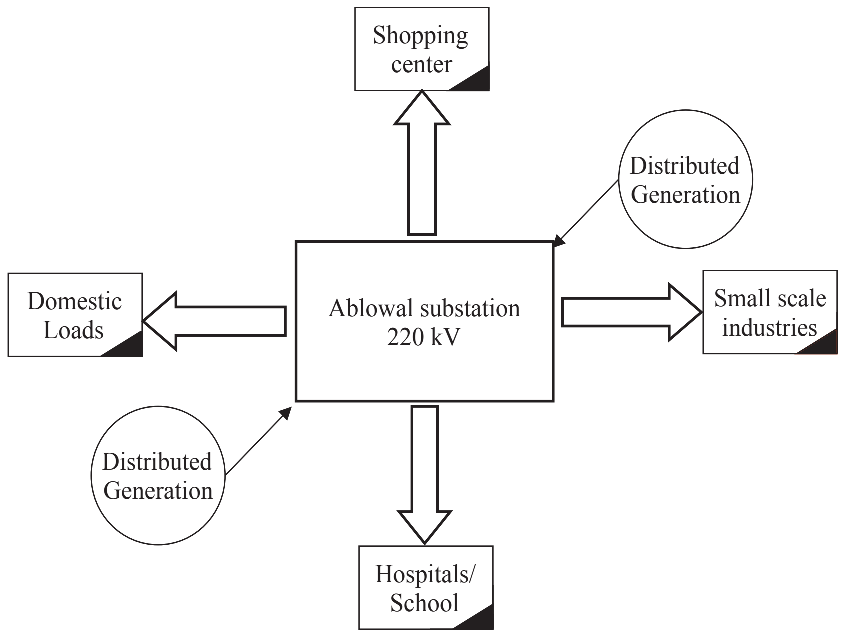

Fig. 3.2: DG power injection in network.

Fig. 3.2 shows the different areas supplied through a 220 kV substation. Also, renewable DG is synchronized to support presently existing distribution system.

According to the previous researches, output power of PV panel rests on atmospheric conditions and geographical location of panel. The output power is denoted by P_{PV} at any time t, which is a function of solar radiation and atmospheric temperature. This can be shown as [38]:

$$P_{PV}(t) = P_{Rat} f_{loss} \frac{G_h}{G_s}[1 + \alpha(T_c - T_s)] \tag{3.5}$$

where P_{Rat} is the rated output power capacity of the PV power panel, f_{loss} is the loss factor of PV panel due to dirt, shadow, temperature, G_h is the hourly solar radiation incident on the solar PV panel (W/m^2), G_s is the standard incident radiation $(1000\ W/m^2)$, α is the temperature coefficient of power, T_c is the PV cell temperature in the current time step and T_s is the PV cell temperature under standard test conditions. This power expression provide an approximate value for power generation through PV system.

3.2.2 Line losses

Generally, the line losses are due to the line impedance and current flowing through it. Line losses are represented as I^2Z where Z represents line impedance. It is distinctive property of line that can not be changed. The conception of current that flows in the feeders or lines of the grid could be abridged to a certainly, if renewable DG units are assimilated with the present distribution system. This will subsidized to a power loss reduction ($\propto I^2$) in line or feeder of system. The outcome of renewable DG on power losses depends on the location, size of the DG, ratings of load and configurations of grid. Nevertheless, inappropriate location, sizing and meager designing of renewable DG units could lead to immoderate power losses and feeder overloading. Therefore, the only way to reduce line losses is by reducing line current [39]. Line current can be expressed as

$$I = \left[\frac{V_i - V_o}{Z_{line}}\right] \tag{3.6}$$

$$Z_{line} = R + iX \tag{3.7}$$

$$R \approx 0 \ and \ X = 2\pi f l \tag{3.8}$$

where R and X are the resistance and impedance parameters of line. For distribution system, R can be neglected [from Equation 3.2].

From Fig. 3.3 it is witnessed that as solar PV power injection took place at any point, localize V increases for that point. Due to increased value of V line current is reduced, which further reduces line losses.

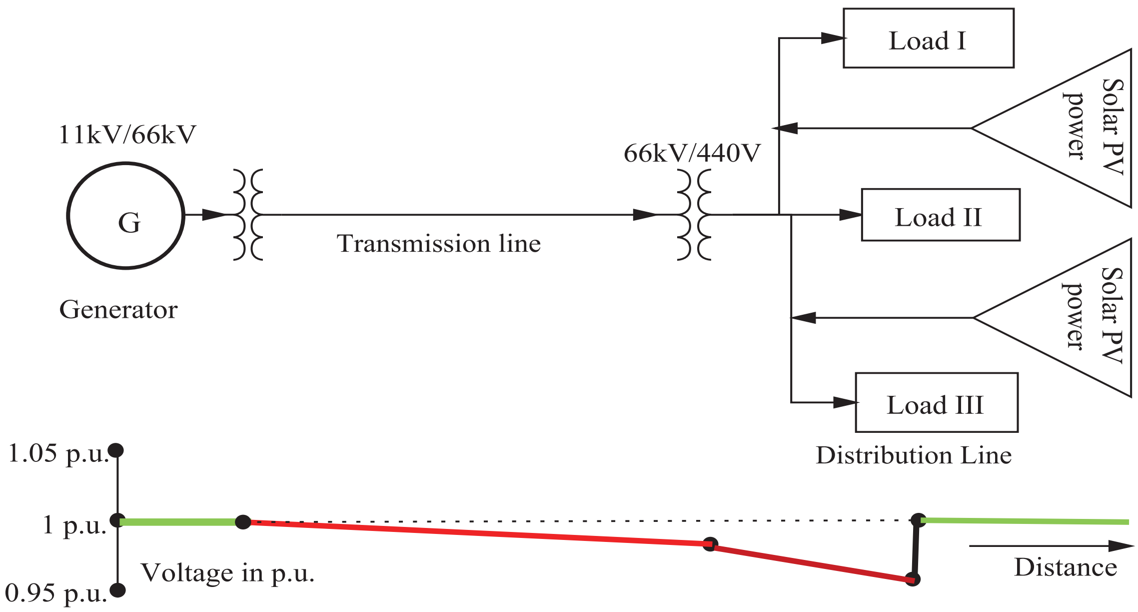

Fig. 3.3: Effect of PV power injection on voltage profile.

During low power requirement from load, excess power supply by DG is supplied to grid by tie grid operation. If the power from solar PV panels $P_{PV}(t)$ is adequate and greater than load demand $P_L(t)$ then load requirement can be straightaway fulfilled by solar power and the leftover power can be sold-out to the grid and can be calculated as:-

$$P_{grid}(t) = [P_{PV}(t) - P_L(t)] \tag{3.9}$$

Where $P_{grid}(t)$ is grid power which is supply back to grid, stored in batteries or wasted.

3.2.3 Effect of voltage change

Flow of either active power or reactive power between any two random points absolutely depends on the magnitude of voltages of points. In Fig. 3.4 shows the bidirectional flow of power both active power and reactive power. Power always flows from higher voltage to lower voltage. V_i is the sending end voltage, V_o is the receiving end voltage, i.e. these are supplied from main grid to whole of the distribution circuit.

Here, PV panels are used to inject DC power in circuit through inverter. The voltage at receiving end is controlled through PV power generation. Moreover, this can work in two modes as explained above based on the demand which has to be fed. During the day time, if load requirement is higher therefore to fulfill the load demand power from grid and PV power plant combines to fulfill the demand. Also, if load requirement is

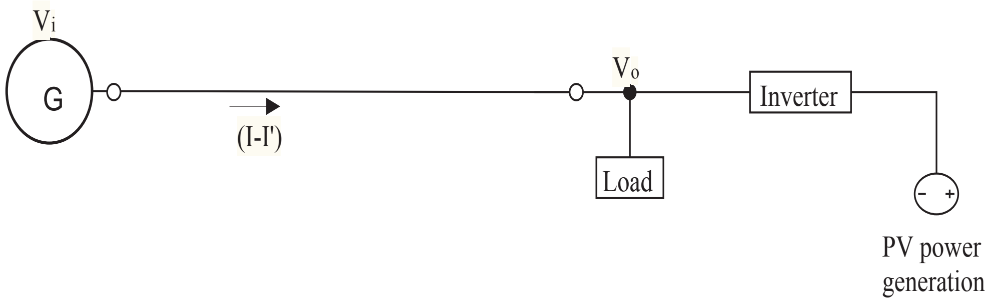

Fig. 3.4: Bidirectional flow of power.

low such that night time, PV power is sufficient to supply load. Also, extra generated power from PV power plant can be supplied to main grid i.e. shown in equations (3.10)-(3.13).

Net voltage V_{net} in circuit which can be responsible for the flow of current:-

$$V_{net} = V_i - V_o \tag{3.10}$$

Now there are three cases:-

- When PV generation is smaller then the load demand. So grid and PV power is combining to supply load.

  $$I = \frac{V_i - V_o}{Z_{line}} \tag{3.11}$$

  Direction of flow of current It is shown in diagram.

- When PV generation is more than the load demand. The load end voltage i.e. V_o is greater and can be expressed as

  $$I' = \frac{V_i - V_o}{Z_{line}} \tag{3.12}$$

  where I' is reverse current from DG source to generation side.

- When generation equal to load demand:-

  $$I = 0 \quad as \quad V_i = V_o \tag{3.13}$$

  Hence, the resultant current is $(I - I')$.

The derived voltage variation formula determine the voltage profile of small as well as large distribution network. Based on the fluctuations in voltage, a voltage control approach is proposed through reactive power compensation. When power is injected from photovoltaic panels it directly affects the node voltage and controls the flow of power (explained with results in next sections). Therefore, by estimating power injection at voltage effected nodes, voltage can directly controlled.

3.2.4 Battery usage

Battery implantation is the another field of study with due respect of a roof top solar power plant. Normally, PV power generation depends on sun light intensity temperature, atmospheric conditions, not on load parameter. Moreover, grid generation is either constant or may lie between a power range of power. At the time of low loading, due to high penetration of power at household level can damage house hold equipments due to sudden or slow rise in voltage. Suggested solution for above discussed problem is "use of battery". Battery made up of lithium oxide which can store the excess of power supplied to load instead of wastage. Also, during peak load demand battery supplies this extra stored power as backup to maintain voltage profile. A fast response of batteries are needed [11].

3.3 Methodology

Renewable DG is projected into the distribution system to improve the voltage contour. It also certifies that voltage established at the load end should be within the unimpeachable range. Supplying a part of active and reactive powers at the synchronizing points by renewable DG system could improve the voltage magnitude. This will bring down the value of current in several sections of the distribution mesh network and encourage the voltage supply to get stiff at the focused consumer load points. Voltage profile and stability is greatly influenced by integration of renewable DG units. Here, direction of flow of power is reversed to reduce the losses in line or feeders of distribution system. Moreover compounding of sustainable DG units into the distribution system could result in greatest release in system capacity by reducing overloading. These objectives can be achieved by finding the allowable location and size of renewable DG units. Onslaught of renewable DG units into the considered network provides a voltage support to increase the LV at the load end of the distribution system to get higher efficiency. Therefore, this is more beneficial to project renewable DG power from distribution end to get observable change in voltage profile in LV network.

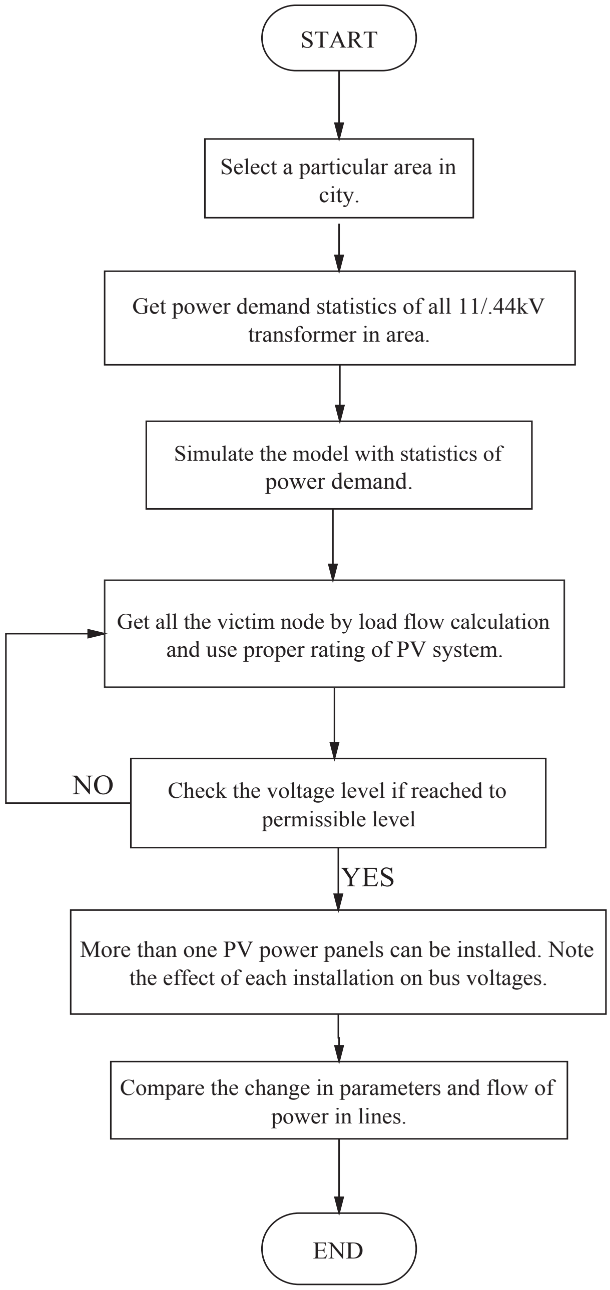

Fig. 3.5: Detailed flow chart.

As explained above, renewable DG directly influences voltage profile of distribution network. This method is tested on a real time distribution network of Patiala, Punjab, India. A distribution area with poor voltage profile is selected as an example whose voltage change can be observed. Amount of PV power injected is in such a way that there should be a considerable change in the magnitude of voltage at different nodes. In Fig 3.5, flow diagram that describe the method to improve voltage profile at any load end.

Selected area is simulated with real time data. Loading at each consumer end is forcast for next 5-7 years when the load gets almost double. After simulation, load flow analysis is performed for the network. All the nodes where voltage change is more than $\pm 5\%$, are selected for PV power injection. This renewable DG power injection also improves voltage profile of neighboring nodes. Actually, power injection from external source reduces the current and increases the stiffness of voltage circuit at victim nodes. Due to diminution of current, line losses ($\propto I^2$) decreases. Also, stiffness in voltage can resist variations due to small or instantaneous change in load. Ratings of PV power injection is decided by calculating increased voltage profile of victim node. Ratings of PV system is decided on the basis of required change in voltage profile. Location and rating of PV power system has to be decided cautiously. A specially designed software "DIgSILENT power factory" is used to calculate load flow for each and every node of simulated network. Load flow report generated by this software is used to compared voltage profiles and line losses after PV power injection.

Fig. 3.6: Roof top PV panel [36].

3.4 Resource data and site selection

A case study of a city, Patiala situated at a coordinate of $76^\circ 12'$ E longitudes and $30^\circ 26'$ N latitude in India is presented in this dissertation. Here load demand is considered for an hour during day. The solar resource statistics for this position is occupied from the NASA surface meteorology website [40]. It is observed that usual solar radiation for this location is 5.14 kWh/m^2/day. Unspoilt amount of solar power make this place usurp to use solar PV power. This case study is modeled by considering a lifespan of 5 to 7 years for load forecasting. Real time data is provided by state load dispatch center, Patiala. Public consult authorities also helped to check results.

Chapter 4

RESULT AND DISCUSSIONS

4.1 Introduction

This chapter describes the simulation and results pertaining to the projected scheme. The purpose of implementation of voltage regulation for an area in Patiala city using distribution generation. PV power injection is used here to improve voltage profile at the load end. Ratings for solar PV plants are 10 kW to 10 MW. Exact ratings are decided by observing voltage status of each consumer end node, accordingly PV power is injected at different locations. Also, injection of PV power in distribution system effects neighbouring nodes. This method successfully completes the objective of this dissertation. Simulation of the whole area of Ablowal substation 220 kV is performed. After simulation it is examined that DIgSILENT power factory persist with some shortcoming. Moreover this software can execute load flow only for 100 node network but this simulated network has above 500 nodes. So, the entire model is divided into 7 different regions [41]. Among these 7 areas, 2 of them are simulated successfully. Load factor is decided according to fore casted load of next 5 to 7 years and also considering future voltage instability problem. Load flow evaluation is performed by DIgSILENT-the power factory software and all the load end node voltages are examined by this report. The two included areas are :-

a). Jail road area of Patiala
b). Anand nagar of Patiala

As observed from generated load flow report, ratings and location of target nodes are examined. In these cases, before and after PV power injection are compared with respect to the voltage profile and line losses. These results can help concern public authorities to sort future voltage problems in distribution system.

4.2 Jail road area

This section deals with analysis of jail road area in Patiala city. This model is selected so that any problem occurring related to voltage instability in future can be easily sorted out. All the related data is provided by SLDC, Patiala. Here, mainly 5 load end nodes are treated as victim nodes. PV power is injected from these 5 nodes to maintain voltage profile of network. Fig 4.1 shows a simulation structure of jail road area. Table 1 shows the status of voltage profile all five nodes.

Table 4.1: Voltage status of all five target nodes.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)
Node 5	0.9	0.6	0.891
Node 26	0.3	0.2	0.90
Node 27	0.3	0.2	0.886
Node 33	0.2	0.1	0.877
Node 43	0.6	0.4	0.806

4.2.1 CASE I : Installing PV plant at node 5.

With the placement of the first PV power plant on node 5, voltage profile is discovered to be improved. First PV power injection takes place at node 5 with the operating point of 500 kW. Ratings and location of power injection is estimated by load flow analysis of the simulated network. Other than node 5, neighboring nodes 3, 8 and 11 are also affected by PV power injection. These results clearly show that DG power not only affects victim node but adjoining nodes also. Maximum change is at node 26 i.e., 0.85 p.u. to 1 p.u. as it is the target node.

Table 4.2 shows a statistical data of change in voltage magnitude after PV power injection. Also, Fig 4.2 shows comparison in voltage profile between and after PV power injection.

Table 4.2: Change in p.u. voltage after projecting first DG set

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 5	0.9	0.6	0.891	1
Node 3	0.3	0.2	0.975	1
Node 8	0.2	0.1	0.976	1
Node 11	0.2	0.1	0.96	1

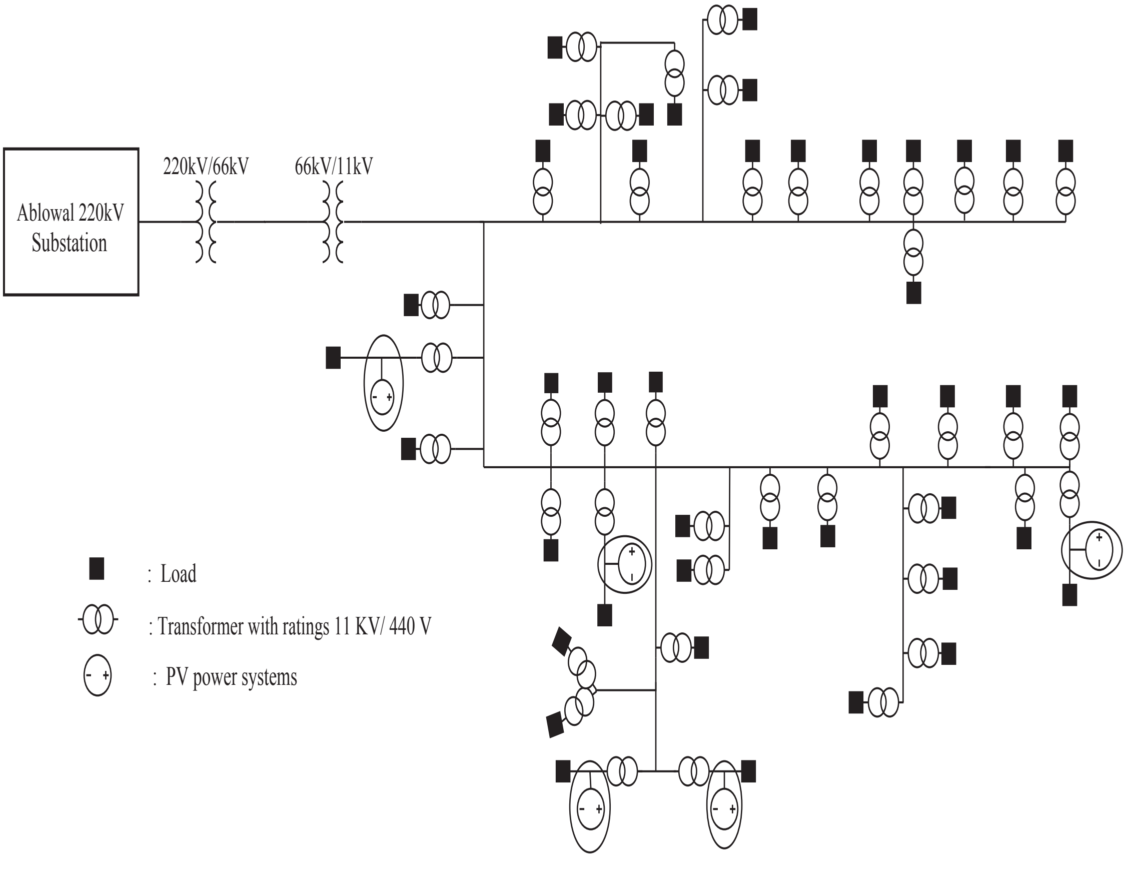

Fig. 4.1: Simulation model indicating the location of PV power location

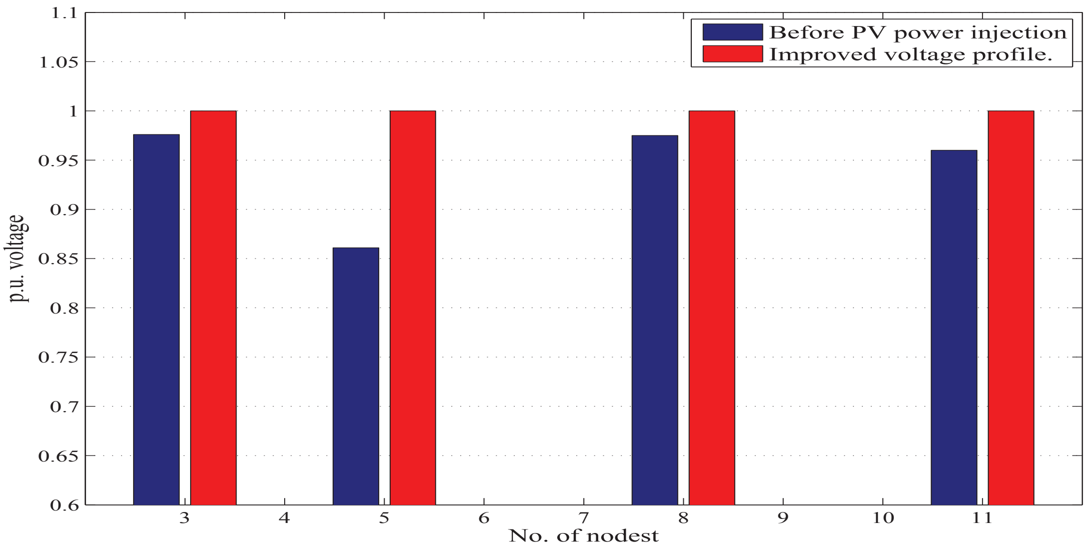

Fig. 4.2: Change in voltages when PV power is injected at node 5

4.2.2 CASE II : Installing PV plant at node 26.

For a further increase in voltage stability, PV system in incorporated into node 26. As power is injected at this node, it affect neighbouring distribution nodes are illustrated in Table 4.3. With required injection of power at node 26, the voltage profile has improved. Moreover, the voltage of 20, 21, 23, 24, 25 and 27 are improved considerably. Before compensation was there, node 27 also suffering from a low magnitude of voltage problem. Due to PV power injection at node 26, the voltage at node 27 changes from 385 V to 440 V.

Fig 4.3 shows the comparative voltage change in the network. Table 4.3 shows the statistical data of voltage profile after PV power injection.

Table 4.3: Change in p.u. voltage after projecting DG power at node 26.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 20	0.1	0.1	0.93	0.96
Node 21	0.1	0.1	0.94	0.98
Node 23	0.1	0.1	0.947	0.967
Node 24	0.6	-0.1	0.96	0.967
Node 25	0.3	0.3	0.96	0.987
Node 26	0.2	0.5	0.9	1
Node 27	0.3	4.5	0.88	0.91

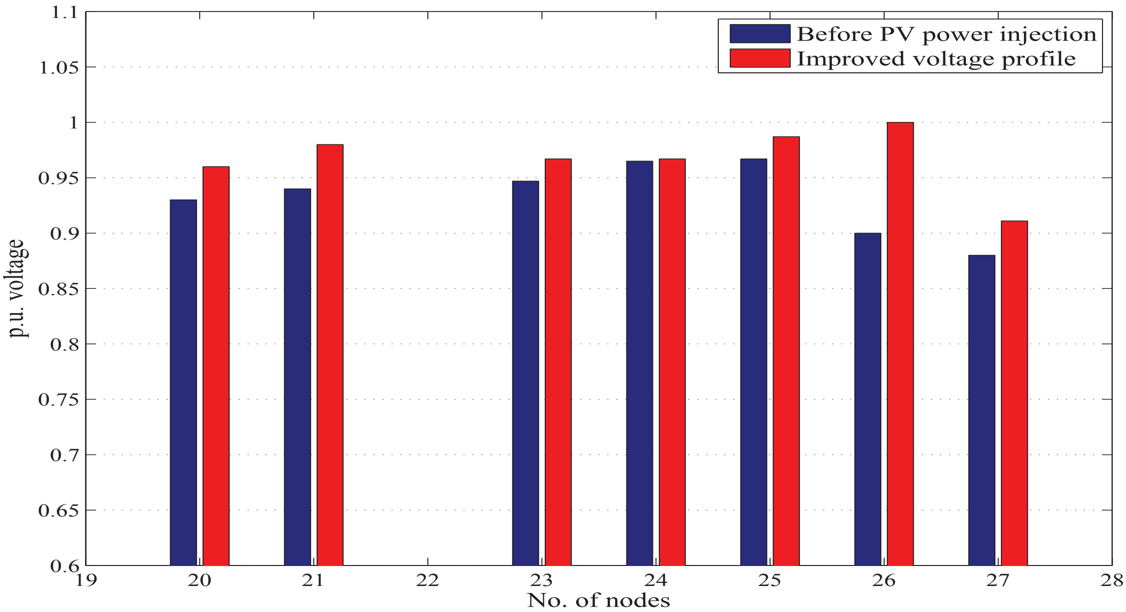

Fig. 4.3: Change in voltage when power is injected at node 26

4.2.3 CASE III : Installing PV plant at node 27.

Third DG power set is placed at node 27. As two PV systems are employed on consecutive nodes i.e. 26 and 27, so neighboring node voltages exceeds the rated value. It explicitly improves the voltage profile of systems. Placement and rating of PV system are equally important. This exceeded values are within permissible range, so it does not affect system stability. Voltage rises to value of 1.006 p.u. value. In this way, DG set contributes to a stable and improved voltage profile. Node no. 18, 19, 20, 14 and 27 are getting affected by power injection from node 27. This PV power injection is proved to be a successful solution for this instability problem. Ratings of PV systems are decided on the basis on evaluation of each node voltage. There are multiple numbers of nodes in the network which are suffering from voltage instability. Incorporating PV power system in distribution system is a difficult task. Renewable DG set is best-appropriate solution for this trouble.

Fig. 4.4 shows a comparative graph showing the change in voltage profile. Table 4.4 shows the p.u. change in voltage in comparative tabular format. It shows the statistical data to describe the voltage change.

Table 4.4: Change in p.u. voltage after projecting DG set at node 27.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 18	0.9	0.7	0.96	1.006
Node 19	0.2	0.21	0.965	1.006
Node 20	0.1	0.1	0.96	1.006
Node 24	0.3	0.2	0.96	1.006
Node 25	0.3	0.3	0.98	1.006
Node 27	0.3	0.2	0.96	1

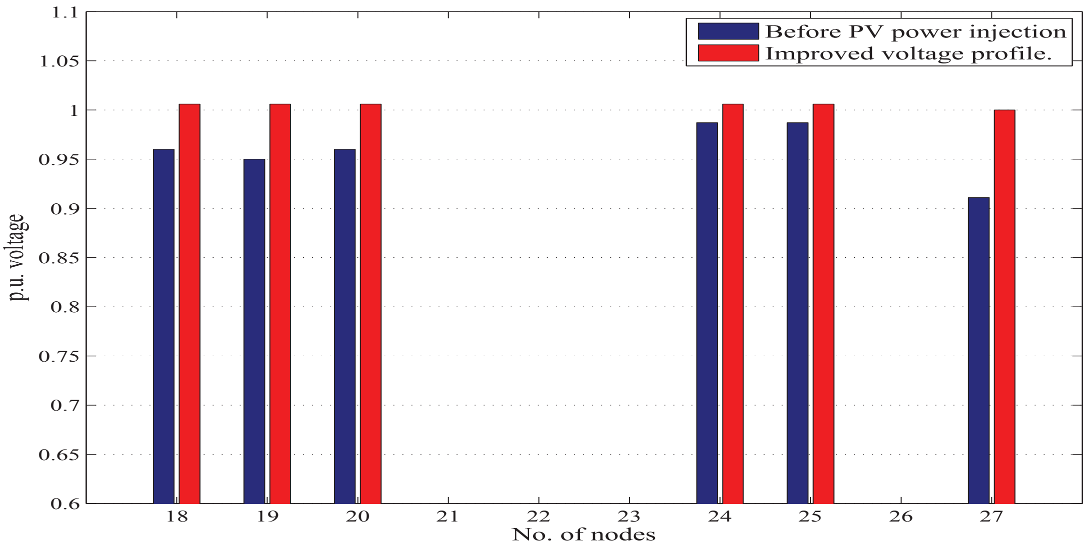

Fig. 4.4: Change in voltage when power is injected at node 27

4.2.4 CASE IV : Installing PV plant at node 33.

The fourth PV system is installed on load node 33. Due to power injection at node 33, the voltage at node 30 is increased to 450 V. Placement of PV system in network is equally important. Other than this node, voltage profile of network is improved. Every node has stable and improved voltage magnitude. Node no. 30, 32, 33 and 36 are getting affected due to power injection from node 33. This renewable DG source makes a noticeable change in voltage profile as shown in the Table 4.5.

All the neighboring nodes are listed in the Table. Node 26, 27 and 33 are consecutive load end nodes where DG is synchronized. Synchronized DG is 500 W rating which is suitable for this node. After node 33, node 43^{rd} is having voltage issue which is solved in next sub-section. A suitable ratings of PV system used 4.48 kW. This value is decided by perceptive load flow report for node 33. Fig 4.5 shows statical comparison in data through bar graphs.

Table 4.5: Change in p.u. voltage after projecting DG set at node 33

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 30	0.2	0.2	0.96	1.032
Node 32	0.3	0.1	0.978	0.978
Node 33	0.2	0.1	0.877	1.0
Node 36	0.1	0.1	0.96	0.96

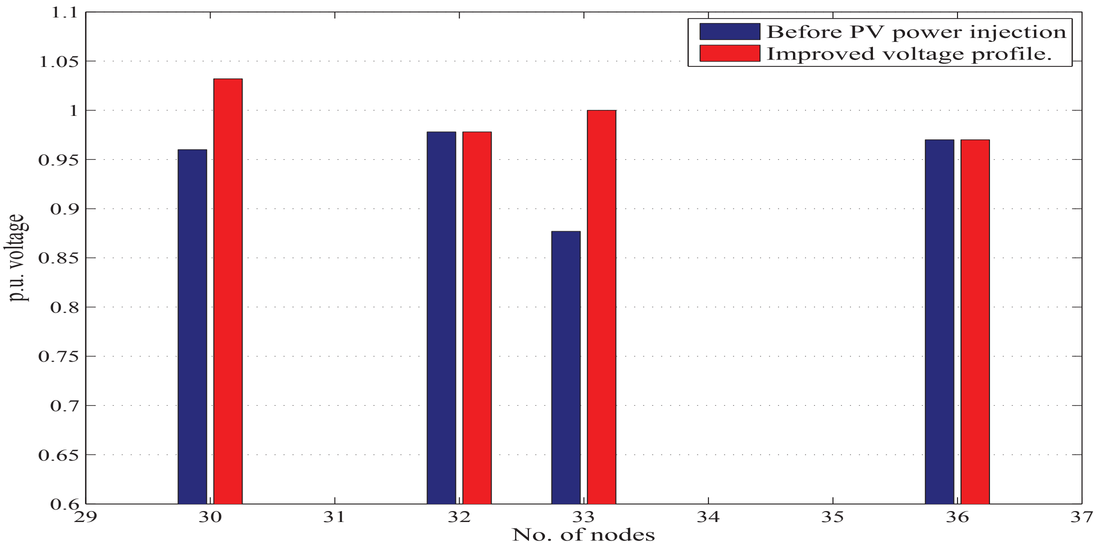

Fig. 4.5: Change in voltage when power is injected at node 33

4.2.5 CASE V :Installing PV plant at node 43.

Now power from DG is extended to node 43. This is the fifth and last node with instable voltage profile. As in previous cases, all the neighboring nodes have improved their voltage profiles. In this use, ratings of PV system is 800 kW. This power injection increases the voltage magnitude by 15%. Placement position of PV system is decided on the basis of report generated in load flow calculation. Along with node no 43, voltage profile of node 41, 45, 47 and 48 is also improving. Fig 4.6, shows improved voltage magnitudes to some neighboring illustrated nodes. Voltage profile get stable with power injection from this node. Voltage magnitude of node 41 has exceeded by rated value but that is not a considerable issue.

All the relevant data is provided by SLDC center, Patiala. This is the last victim node, which is examined by this power injection method. Table 4.6 shows a comparative statistical change in voltage. Fig 4.6 shows comparative change in voltage magnitude after PV power injection.

Table 4.6: Change in p.u. voltage after projecting DG set at node 43

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 41	0	0	0.96	1.003
Node 43	0.6	0.4	0.8	0.997
Node 45	0.5	0.3	0.95	0.977
Node 47	0.3	0.1	0.95	0.97
Node 48	0.3	0.2	0.96	0.98

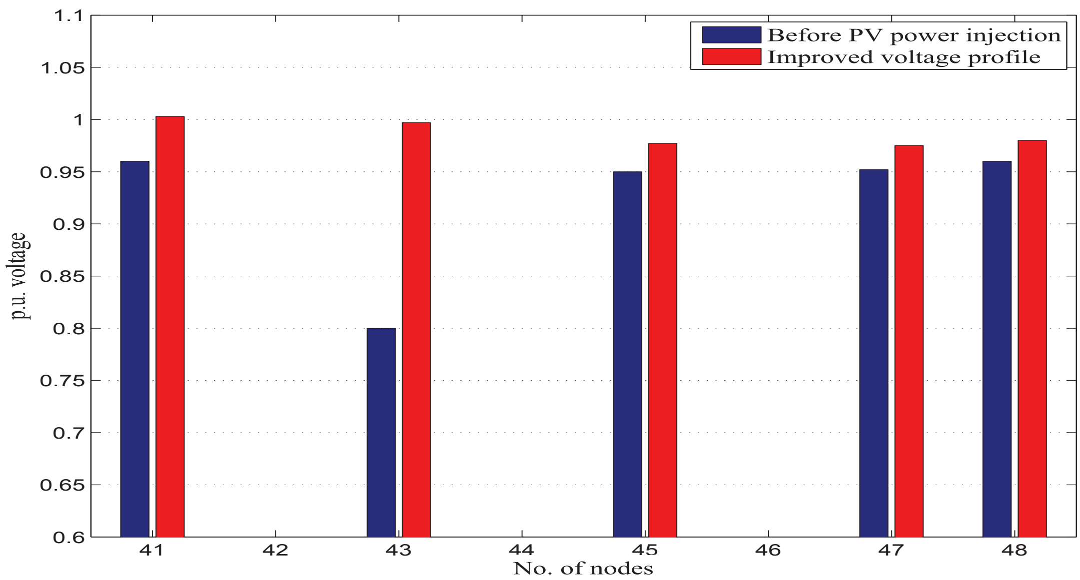

Fig. 4.6: Change in voltage when power is injected at node 43.

4.3 Anand nagar area

This section includes the analysis of another area under Ablowal 220 kV substation of Patiala city. Anand nagar area is considered for examination and improvement of voltage profile. Here, 5 victim nodes are incurred similar to the previous model. Study with placement of DG at each node is done and change in voltage profile of network is observed. These changes are compared with the help of bar graphs as done in the previous case.

All the relevant data is provided by concern public authority of Patiala city. This analysis results can also be used by this authority. Fig 4.8 shows the simulated model of Anand nagar area.

Table 4.7: Voltage status of all five target nodes.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)
Node 11	0.7	0.5	0.689
Node 25	1.0	0.2	0.833
Node 33	1.0	00	0.913
Node 50	0.8	0.6	0.687
Node 68	0.6	0.5	0.86

4.3.1 CASE I: Installing PV plant at node 11.

With the placement of first PV power plant on node 11, voltage profile is discovered to be improved for neighbouring node. First PV power injection takes place at node with operating point of 500 kW. Ratings and location of PV power injection are estimated by load flow report of the simulated network. Rating and placing of PV systems are equally important for network. Other than node 11, neighboring nodes 7, 12, 14 and 16 are also affected by PV power injection. Repetitively, it is observed that placement of PV system at any node effects the other load nodes. Change in voltage is mainly observed in neighboring locality. Ratings of the PV power systems are decided according to change in status of voltage after injection.

Fig 4.7 shows a comparative change in voltage status. Table 4.8 shows statistically change in data in voltage magnitude. This shows a statistical comparison between different node voltages through bar graphs.

Table 4.8: Change in p.u. voltage after projecting DG set at node 11.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 7	0.9	0.3	0.731	1.0
Node 11	0.7	0.5	0.689	1.036
Node 12	0.5	0.1	0.89	0.973
Node 14	0.9	0.1	0.86	0.92
Node 16	0.5	0	0.86	0.97

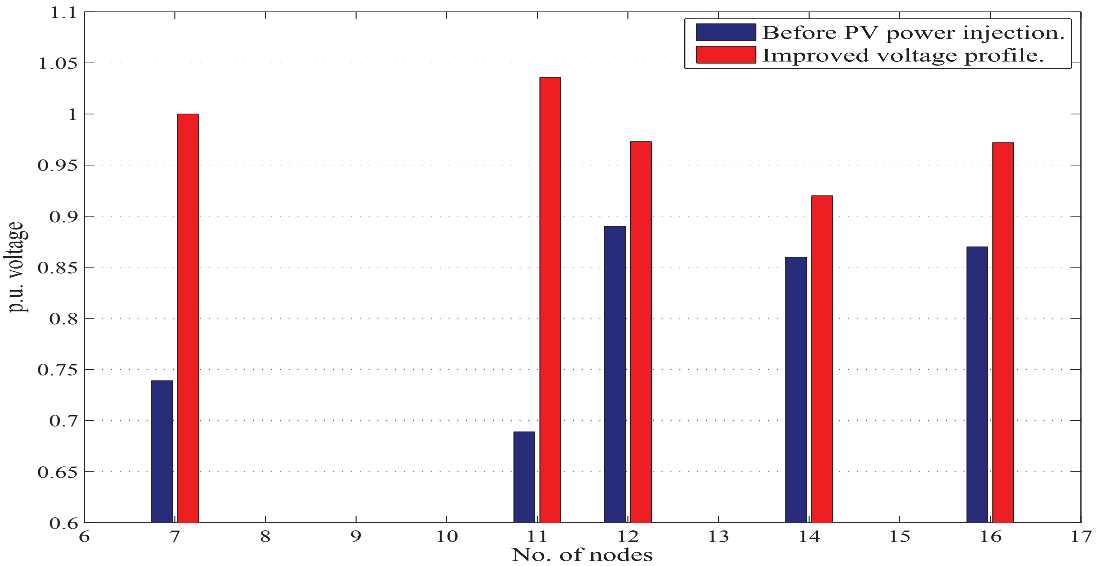

Fig. 4.7: Comparative change in voltage when power is injected at node 11

4.3.2 CASE II : Installing PV plant at node 25.

For more improvement in voltage stability, PV system in incorporated at node 25. As power is injected from this node, it affects neighbor distribution nodes as illustrated in Table 4.9. Placement of DG at node 25 not only greatly enhance voltage stability of that node, but also improves the voltage of 20, 23, 25, 27 and 29 to a considerable extend. Node 27 also suffering from the low magnitude of voltage problem. Node no. 23, 25 and 26 are getting affected due to power injection from node 25. Ratings and locations are suggested on the basis of load flow report of simulation. Ratings and location both are equally important for the installation of PV power systems.

Table 4.9: Change in p.u. voltage after projecting DG at node 25.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 23	0.6	0.0	0.92	0.96
Node 25	0.7	0.3	0.833	1.003
Node 27	1.0	0.3	0.9	0.97
Node 29	1.0	0.3	0.89	0.97

Table 4.9 shows particular load rating at respective nodes. Fig 4.9 depicts change in voltage levels after injecting PV power at node 25.

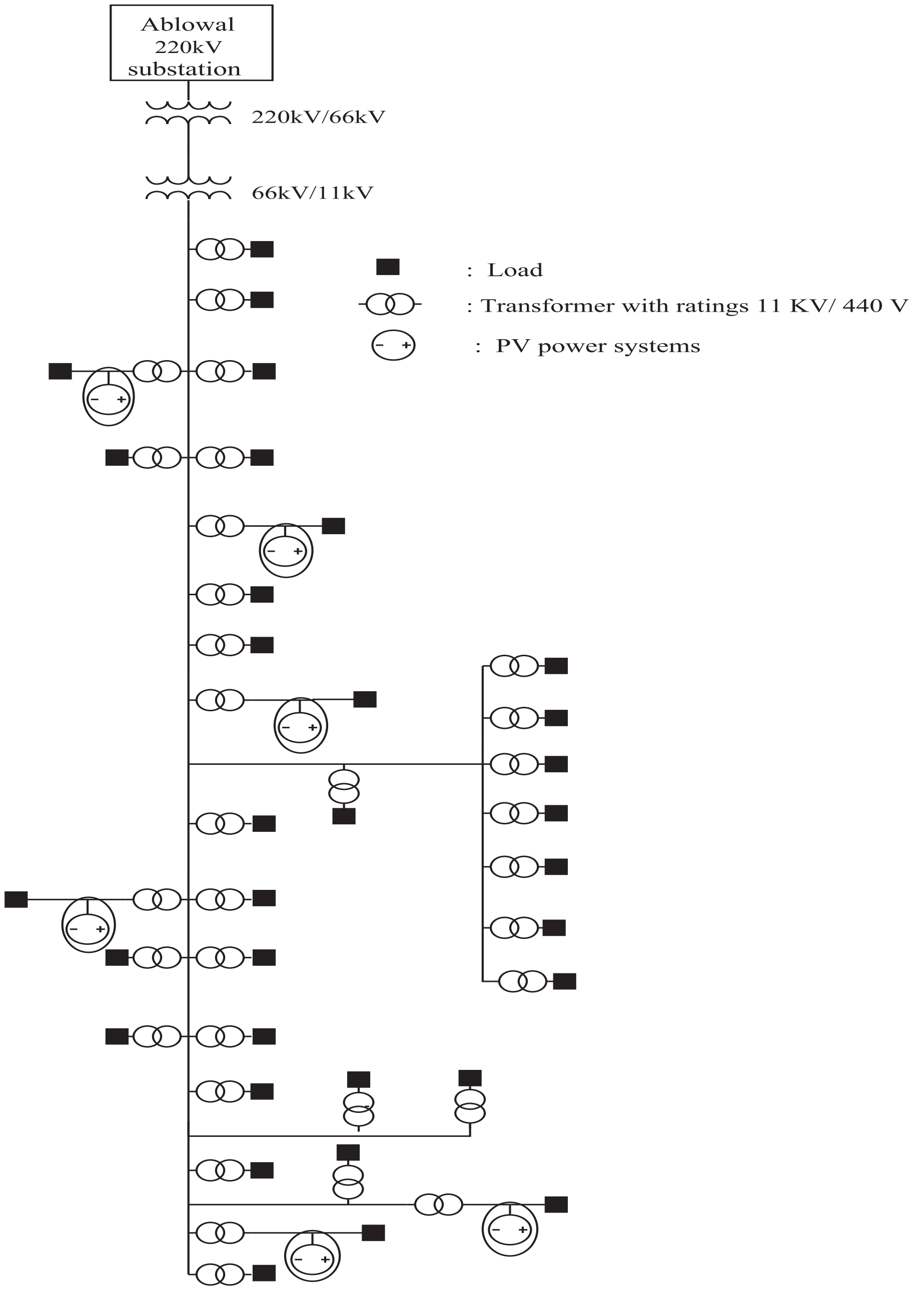

Fig. 4.8: Simulation model of Anand nagar indicating the location of PV power injection

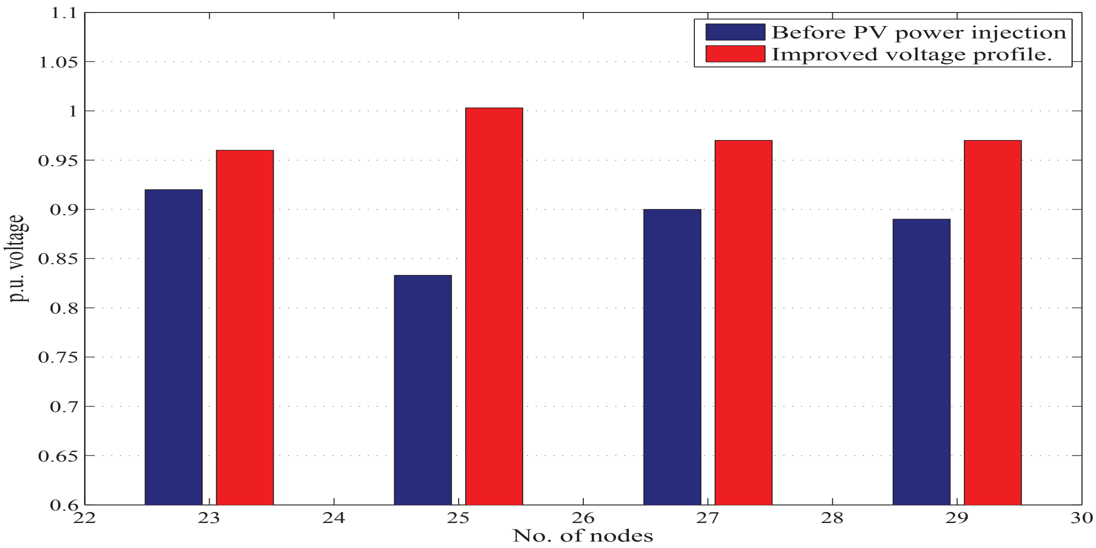

Fig. 4.9: Change in voltage when power is injected at node 25

4.3.3 CASE III : Installing PV plant at node 33.

Third DG power set is placed on node 33. After injected 4.5 kW PV power at node 33. Node no. 29, 31, 33 and 36 are getting affected by power injection from node 33. Voltage rise can be examined on listed nodes. This PV power injection is proved to be a successful solution for this voltage instability problem. With placement of PV power source, voltage magnitude improves at the load end improves. For different time zone in a day, PV system has variable output. The rating and loading of DG to be incorporated into distribution system is divided by load flow analysis done through DIgSILENT power factory software.

Renewable DG set is best-appropriate solution for this problem. Fig 4.10 shows a comparison in voltage magnitude after PV power injection. Comparison results shows that neighbouring node are also greatly affected. Table 4.10 shows the statistical data of change in data after PV power injection.

Table 4.10: Change in p.u. voltage after projecting DG set at node 33.

Bus no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 29	0.95	0.3	0.9	0.98
Node 31	0.4	0.1	0.92	0.97
Node 33	1	0	0.913	1
Node 36	1.0	0.5	0.94	0.95

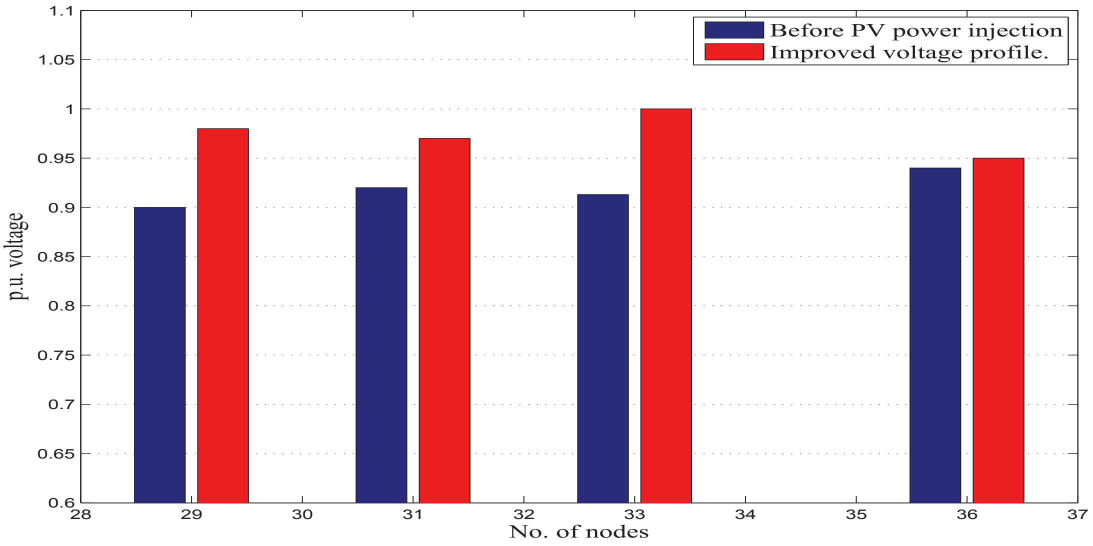

Fig. 4.10: Change in voltage when power is injected at node 33.

4.3.4 CASE IV : Installing PV plant at node 50.

The fourth PV system is installed at load node 50. Due to power injection at node 50, the voltage at node 50 is reached to rated value which in desired. Other than this node, voltage profile of entire network is improving. Every node has stable and improved voltage magnitude. Node no. 51, 54 and 55 are getting affected due to power injection from node 50. With every placement of PV system at the distribution network, voltage stability increases. Rating and placement location are equally important for this network. It is indulged with various problems including synchronization of PV power with network. This improvement can be estimated by load flow report generated by simulation. This renewable DG source makes a noticeable change in voltage profile as shown be Table 4.11. All the neighboring nodes are listed in respective table. The analysis of this network shows that 4.48 kW DG is suitable for voltage profile improvement at this node.

Table 4.11: Change in p.u. voltage after projecting DG set at node 50

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 50	0.8	0.6	0.7	1.0
Node 51	0.4	0.1	0.9	0.9
Node 54	0.1	0.3	0.89	0.92
Node 55	0.1	0.1	0.87	0.96

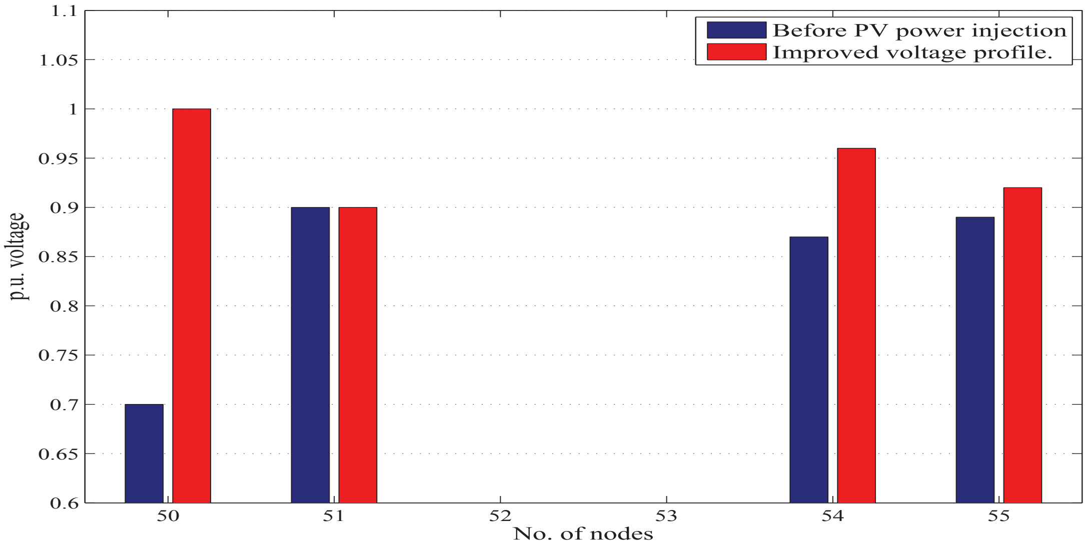

Fig. 4.11: Change in voltage when power is injected at node 50

Table 4.11 shows the load ratings for particular affected nodes. Change in voltage can be observed through the load flow report. Fig 4.11 describe the change in voltage magnitude after PV power injection. A comparative study of both cases are determined through bar graph.

4.3.5 CASE V : Installing PV plant at node 68.

Now DG power is forwarded through node 68. This is the fifth and last node for considered network. It was repeatedly observed that voltage profile of neibhouring nodes improved again to a considerable extend. Ratings of PV power injection is 800 kW. Along with node no 68, voltage profile of node 66, 70 and 72 is also improving. Rating and placement location of PV power system in the network are equally important for this network.

Table 4.12: Change in p.u. voltage after projecting DG set at node 68.

Node no.	P_i (MW)	Q_i (MVAr)	V_{load} (p.u.)	V_{new} (p.u.)
Node 41	0	0	0.96	1.003
Node 43	0.6	0.4	0.8	0.997
Node 45	0.5	0.3	0.95	0.977
Node 47	0.3	0.1	0.95	0.97
Node 48	0.3	0.2	0.96	0.98

Table 4.12 depicts the statistical change in voltage magnitude due to PV power injection. All the relevant data is provided by SLDC center, Patiala. This is the last victim node, which is corrected by this power injection. Change in voltage is observed by load flow results generated by respective software. The injection of PV power from DG source are considerably improving stability of voltage profile of the distribution network. Above results can be used to tackle future problems regarding voltage instabilities.

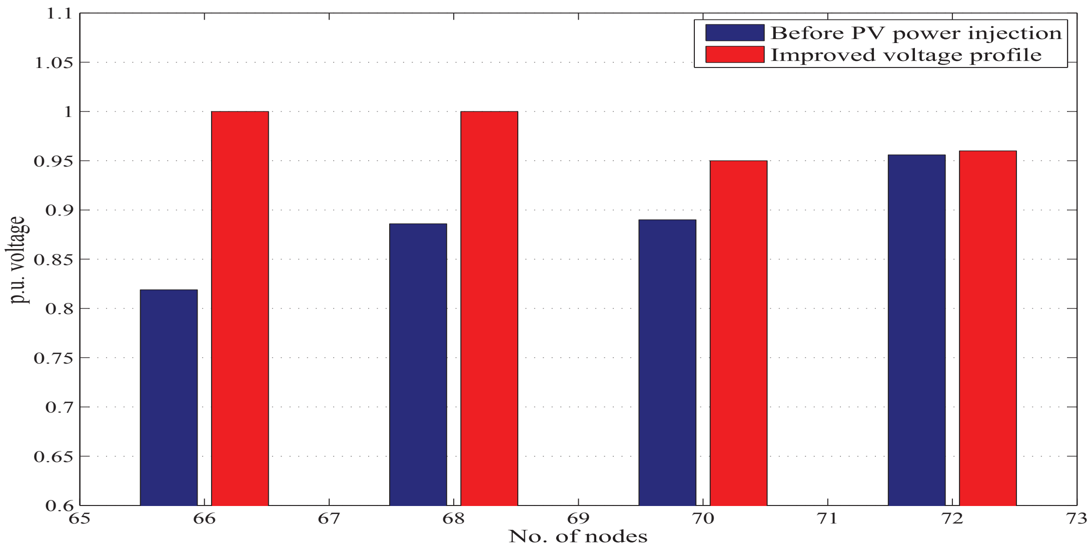

Fig. 4.12: Change in voltage when power is injected at node 68.

Chapter 5

CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

In the present study, Ablowal 220 kV substation of Patiala, Punjab was found as the region with high voltage instability. The real time model was then simulated and analyzed using DIgSILENT: power factory software. The analysis presented in this dissertation is different from conventional approach. The varied locations of the voltage instability in the distribution system was inferred from the simulation outcomes. Power through photovoltaic system was used to regulate the problem of voltage instability. PV power was injected at the valid location of voltage instability in the distribution system to cause an distribution system to cause an improvement in the voltage profile of the network.

The improved voltage profile attained by injection of PV power was then compared with the analytical methods and it was found that PV power injection method is most recommended method for voltage regulation. The region of voltage instability were identified in distribution system. The power injection through PV system is highly useful in regulating voltage.

5.2 Future scope of the work

In the present study, the voltage regulation was restricted to a single substation area of Patiala city. PV power injection method to regulate voltage can be extended to whole Patiala city network.

Voltage instability is a major concern in the present distribution system. Therefore, usage of PV power injection method over real time larger areas would be very cost effective and eco-friendly. This reason gives edge to this method over others.

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LIST OF PUBLICATIONS

1. Aakarti Sethi, Shakti Singh and Mukesh Singh, "Controlling of Consumer End Voltage Variation using PV Power Generation", 7^{th} IEEE India International Conference on Power Electronics, IICPE-2016 1570318883, Thapar University, Patiala, India, November 1719, 2016. (Accepted and Presented).

2. Aakarti Sethi, Shakti Singh and Mukesh Singh, "Feasibility Study of Probable Location of Photovoltaic System in Patiala Distribution Network". Manuscript under preparation.

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ACADEMIC DETAILS

Examination	University/ Intitute	Specialization	Year	CPI/%
Post Graduation	Thapar University	Power Systems	2017	83
Graduation	RTU	Electrical	2014	67
12^{th}	CBSE	NPS, Ganganagar	2010	68
10^{th}	CBSE	KV, STPS township	2008	83

Aakriti

Aakarti Sethi

ANNEXTURE

Table 5.1: Data provided by state load dispatch center, Patiala.

OBJECTID.	Feeder name	Vector	LV	HV	kVA
144550	Anand nagar	DYN11	0.44	11	63
144551	Anand nagar	DYN11	0.44	11	100
144552	Anand nagar	DYN11	0.44	11	63
144553	Anand nagar	DYN11	0.44	11	200
144554	Anand nagar	DYN11	0.44	11	200
144555	Anand nagar	DYN11	0.44	11	100
144556	Anand nagar	DYN11	0.44	11	100
144557	Anand nagar	DYN11	0.44	11	100
144558	Anand nagar	DYN11	0.44	11	100
144559	Anand nagar	DYN11	0.44	11	200
144560	Anand nagar	DYN11	0.44	11	200
1445561	Anand nagar	DYN11	0.44	11	100
144562	Anand nagar	DYN11	0.44	11	200
144563	Anand nagar	DYN11	0.44	11	200
144564	Anand nagar	DYN11	0.44	11	100
144565	Anand nagar	DYN11	0.44	11	100
144566	Anand nagar	DYN11	0.44	11	100
144567	Anand nagar	DYN11	0.44	11	100
144568	Anand nagar	DYN11	0.44	11	100
144569	Anand nagar	DYN11	0.44	11	300
144570	Anand nagar	DYN11	0.44	11	100
144571	Anand nagar	DYN11	0.44	11	100
144572	Anand nagar	DYN11	0.44	11	200
144573	Anand nagar	DYN11	0.44	11	300
144574	Anand nagar	DYN11	0.44	11	100
144575	Anand nagar	DYN11	0.44	11	100
144576	Anand nagar	DYN11	0.44	11	200

OBJECTID.	Feeder name	Vector	LV	HV	kVA
144577	Anand nagar	DYN11	0.44	11	100
144578	Anand nagar	DYN11	0.44	11	200
144579	Anand nagar	DYN11	0.44	11	100
144580	Anand nagar	DYN11	0.44	11	100
144581	Anand nagar	DYN11	0.44	11	100
144582	Anand nagar	DYN11	0.44	11	100
144583	Anand nagar	DYN11	0.44	11	100
144584	Anand nagar	DYN11	0.44	11	200
144585	Anand nagar	DYN11	0.44	11	100
144586	Anand nagar	DYN11	0.44	11	100
144587	Anand nagar	DYN11	0.44	11	200
144990	Jail road	DYN11	0.44	11	200
144991	Jail road	DYN11	0.44	11	100
144992	Jail road	DYN11	0.44	11	100
144993	Jail road	DYN11	0.44	11	100
144994	Jail road	DYN11	0.44	11	63
144995	Jail road	DYN11	0.44	11	100
144996	Jail road	DYN11	0.44	11	100
144997	Jail road	DYN11	0.44	11	100
144998	Jail road	DYN11	0.44	11	100
145002	Jail road	DYN11	0.44	11	200
145003	Jail road	DYN11	0.44	11	100
145004	Jail road	DYN11	0.44	11	100
145005	Jail road	DYN11	0.44	11	100
145006	Jail road	DYN11	0.44	11	100
145007	Jail road	DYN11	0.44	11	100
145008	Jail road	DYN11	0.44	11	100
145009	Jail road	DYN11	0.44	11	100
145010	Jail road	DYN11	0.44	11	100
145011	Jail road	DYN11	0.44	11	100
145012	Jail road	DYN11	0.44	11	200
145013	Jail road	DYN11	0.44	11	100
145014	Jail road	DYN11	0.44	11	100
145016	Jail road	DYN11	0.44	11	100
145032	Jail road	DYN11	0.44	11	100
145033	Jail road	DYN11	0.44	11	100
145034	Jail road	DYN11	0.44	11	100
145035	Jail road	DYN11	0.44	11	100
145036	Jail road	DYN11	0.44	11	63
145037	Jail road	DYN11	0.44	11	100
145038	Jail road	DYN11	0.44	11	100

OBJECTID.	Feeder name	Vector	LV	HV	kVA
145039	Jail road	DYN11	0.44	11	100
145040	Jail road	DYN11	0.44	11	100
145041	Jail road	DYN11	0.44	11	63
145042	Jail road	DYN11	0.44	11	100
145043	Jail road	DYN11	0.44	11	100
145044	Jail road	DYN11	0.44	11	100
145045	Jail road	DYN11	0.44	11	100
145046	Jail road	DYN11	0.44	11	100
145047	Jail road	DYN11	0.44	11	100
145048	Jail road	DYN11	0.44	11	100
145049	Jail road	DYN11	0.44	11	100
145050	Jail road	DYN11	0.44	11	100
145051	Jail road	DYN11	0.44	11	200
145052	Jail road	DYN11	0.44	11	100
145053	Jail road	DYN11	0.44	11	100
145054	Jail road	DYN11	0.44	11	100
145055	Jail road	DYN11	0.44	11	200
145056	Jail road	DYN11	0.44	11	100
145057	Jail road	DYN11	0.44	11	100
145058	Jail road	DYN11	0.44	11	200
145059	Jail road	DYN11	0.44	11	100
145060	Jail road	DYN11	0.44	11	100
145061	Jail road	DYN11	0.44	11	100
145062	Jail road	DYN11	0.44	11	100
145063	Jail road	DYN11	0.44	11	100
145064	Jail road	DYN11	0.44	11	100
145065	Jail road	DYN11	0.44	11	63
145066	Jail road	DYN11	0.44	11	100
145067	Jail road	DYN11	0.44	11	100
145068	Jail road	DYN11	0.44	11	100
145069	Jail road	DYN11	0.44	11	100
145070	Jail road	DYN11	0.44	11	100
145071	Jail road	DYN11	0.44	11	200
145072	Jail road	DYN11	0.44	11	100
145073	Jail road	DYN11	0.44	11	100
145074	Jail road	DYN11	0.44	11	100
145075	Jail road	DYN11	0.44	11	100
145076	Jail road	DYN11	0.44	11	100
145077	Jail road	DYN11	0.44	11	100
145078	Jail road	DYN11	0.44	11	100
145079	Jail road	DYN11	0.44	11	100
145080	Jail road	DYN11	0.44	11	100
145081	Jail road	DYN11	0.44	11	100
145082	Jail road	DYN11	0.44	11	100

220 KV Ablowal SS

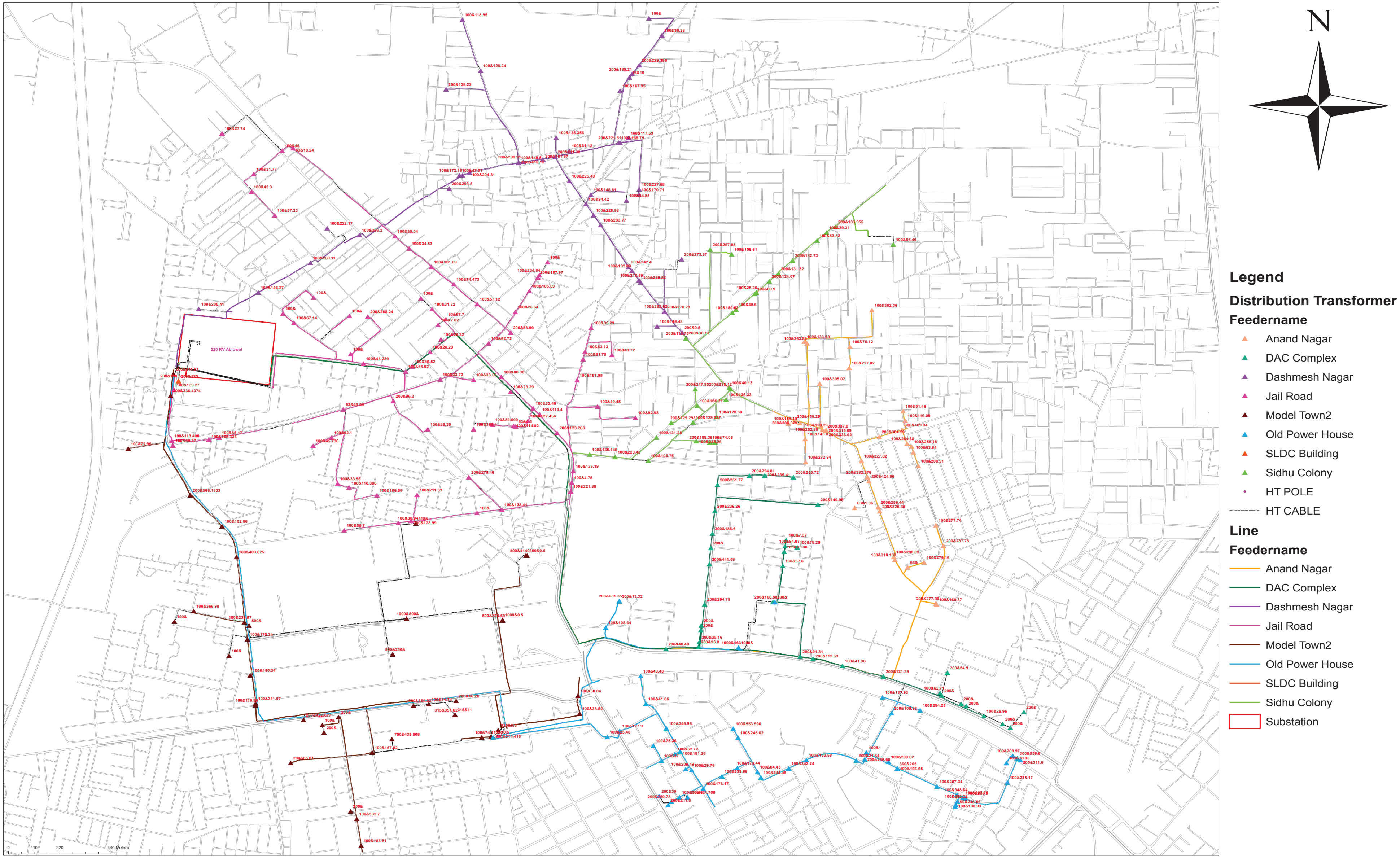

Fig. 5.1: Map of distribution network under Ablowal 220 kV substation.

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ORIGINALITY REPORT

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Singh, Shakti, and Subhash Chandra Kaushik. "Optimal sizing of grid integrated hybrid PV-biomass energy system using artificial bee colony algorithm", IET Renewable Power Generation, 2016. Publication	%1
2	eeeic.eu Internet Source	%1
3	ro.uow.edu.au Internet Source	%1
4	vssut.ac.in Internet Source	%1
5	Adefarati, T, and R. Bansal. "Integration of Renewable Distributed Generators into the Distribution System: A Review", IET Renewable Power Generation, 2016. Publication	%1
6	gdeepak.com Internet Source	<%1