
VOLTAGE CONTROL IN THE PRESENCE OF DISTRIBUTED GENERATION

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ABSTRACT

Large volume of distributed power generators (DGs) including renewable distributed generation will be introduced in a distribution network in the near future. Voltage is an important parameter for the control of electrical power systems. The distribution network operators have the responsibility to regulate the voltage supplied to consumer within statutory limits. This paper presents a technique using Static Var Compensator (SVC) for voltage control in a distribution system in the presence of DGs. In order to avoid maximum permitted voltage when DG power is high, SVC was placed in the network alongside the DGs; the result presented shows a voltage profile, power quality improvement and distribution loss reduction.

Keywords: Distributed Generation (DG), Distribution Network (DN), Static Var Compensator (SVC)

INTRODUCTION

Distributed Generator can be alluded as little generating unit connected to the distribution network, which was not centrally dispatched and planned. Set of such generators can be called as Distributed generation (DG). The fundamental purpose for less generation by centrally located power plants is the time taken for the construction of power plants. They include higher level of pollution as thermal power plants have vast share in conventional power generating units. Advantages of distributed generation include power reliability and quality, transmission and distribution support, energy price risk, environmental performance and some localized financial benefits [1].

DG mainly tries to extract clean energy from natural resources which are renewable sources of energy. Hydro generations and photovoltaic are some illustrations of this kind. Frequently DG utilizes energy efficient and sustainable methods of power generation. Fuel cells and micro turbine comes into this class. There are more DG technologies like geothermal energy and tidal energy. These are not popular as of now because of difficulty in changing them to electrical power.

Voltage is one of the critical parameters for the control of electric power systems. The On-Load Tap Changer (OLTC) transformers is a customary system that is utilized between these numerous voltage levels to direct and maintain the voltage which is supplied to consumers within statutory limits. The OLTC voltage regulation is actually operated by changing the number of

turns in one winding of the transformer to physically adjust the ratios of the transformer. The On-Load Tap Changer (OLTC) transformers are utilized between these various voltage levels to regulate and maintain the voltage which is supplied to consumers within statutory limits. [2].

The twin issues of global warming and exhaustion of fossil fuels have seen an expansion in the usage of distributed generation, for example cogeneration system of high thermal efficiency, clean natural energy generation and many others as of late. Huge numbers of the distributed generations are set up in the region of the customer, and there is an advantage that this has a short period of construction, decreases transmission loss and low investment risk. On the other hand, the natural energy power generation of photovoltaics, wind power, etc., which is distributed generation, is affected by meteorological conditions. In this way, the distributed generation connected to the downstream power system may create backward flow which is not assumed in conventional systems. The flow of electric power is unidirectional, from an upstream to a downstream system in the conventional electric power system. Along these lines, voltage control of an electric power system proposes the state of the flow of electric power as unidirectional. At this point, when distributed generation increases, by the conventional control procedure, it is expected that voltage variation of each node turns an issue. All together for voltage variation not to damage the equipment and other devices of the user, consumer voltage ought to be kept within a range. [3]

In a radial distribution feeder, voltage diminishes towards the end of the feeder, as loads cause a voltage drop. In any case, it will be adjusted with the presence of DG. DG will build the voltage at its connection point, which thusly will increase the voltage profile along the feeder [4]-[5]. This increase might surpass the greatest permitted voltage when the DG power is high. One approach to mitigate this overvoltage is when DG

retains reactive power from the network. This strategy is viable for mitigation of overvoltage-caused DG in low voltage (LV) feeders where the mean of voltage control is gotten from an off-load tap changer. In any case, if DG absorbs reactive power, feeder losses will increase.

Voltage control is one of the important control schemes at a distribution substation, which expectedly includes regulation of reactive power and voltage at substation bus [6], [7]. The voltage control can be accomplished by utilizing voltage controllers. In this paper, some methods will be reviewed and SVC technique will be presented.

TECHNIQUE FOR VOLTAGE CONTROL

A. Automatic Voltage Control

The essential operation and the general arrangement of a simple automatic voltage control (AVC) relay and OLTC with the comparison between target voltage and load voltage; the AVC relay figures out whether to change the tap position or not so as to keep up the required voltage level. To manage the voltage control issues together with the expanding penetration of the DGs, Distribution Network Operators (DNOs) require more effective and stable OLTC voltage control schemes [8]. This basic mathematical equation (1) can be utilized to dissect subjectively the relationship between the voltage at bus in any distribution network and the amount of generation that can be connected to the distribution system, and in addition the effect of alternative control actions which is shown in Fig. 1.

$$V_2 \approx V_1 + R(P_n - P_L) + (\pm Q_n - Q_L \pm Q_C)X \tag{1}$$

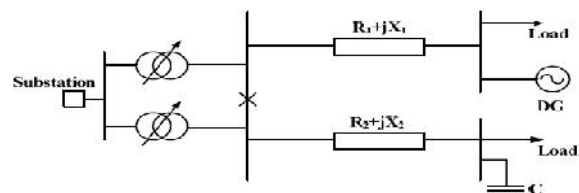


Fig. 1: Simple system for voltage control

B. Synchronous Condenser

Synchronous condenser has played a major voltage and reactive power control. They have been both transmission and sub transmission voltage level to maintain voltage and improve stability with in desired limit under varying load condition and possibility circumstance. The control of voltage levels is accomplished by controlling the absorption, generation and flow of reactive power at all levels in the system. The producing units give the fundamental method for voltage control. The automatic voltage regulators control field excitation to keep up a scheduled voltage level at the generators terminals. Extra means are generally required to control voltage all throughout the system [9]. The voltage control issue is regularly called the reactive power control problem since the terminal voltage of a synchronous generator is controlled by differing its reactive power output through the activity of the excitation system [10].

C. Regulate Voltage

The On-Load Tap Changer (OLTC) transformer furnished with automatic voltage control (AVC) relays is the most famous and powerful voltage control device [11]. There are different control qualities connected with OLTC, such as time grading for accommodation operation in series of transformers, Line Drop Compensation (LDC) as well as a variety of circulating current compensation methods for operation of parallel transformers. This voltage drop along the feeder impedance is utilized to help the voltage controlled at the transformer terminal subsequently guaranteeing the right voltage level keeps up the load where it is required. The LDC gives voltage control at a nominal load point as opposed to the transformer terminals as shown in Fig. 2 [12].

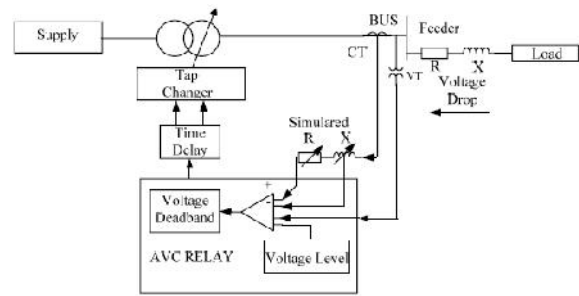


Fig. 2: AVC relay scheme with LDC

Voltage Control in the Presence of DG Using SVC.

Voltage is a standout amongst the most imperative parameters for the control of electric power systems. In a radial distribution feeder, voltage diminishes towards the end of the feeder, as loads cause a voltage drop. On the other hand, it will be adjusted with the presence of DG. DG will build the voltage at its connection point, which thusly will expand the voltage profile along the feeder [13]. This expansion might surpass the greatest permitted voltage when the DG power is high.

The On-Load Tap Changer (OLTC) transformers which are the major type for voltage control are utilized between these different voltage levels to maintain and regulate the voltage which is supplied to consumers within statutory limits. Different methods of voltage control are synchronous condenser and static var compensator (SVC).

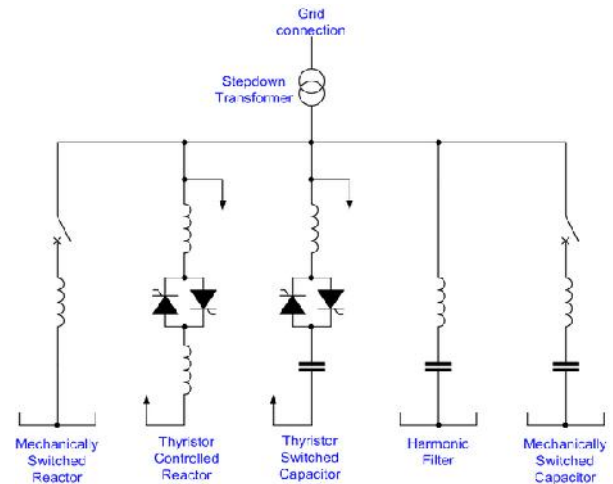


Fig. 3: Symbol of SVC

A Static Var Compensator (SVC) is a power quality device, which employs power electronics to control the reactive power flow of the system where it is connected. Thus, it can give quick acting reactive power compensation on electrical systems. The SVC is an automated impedance coordinating device, intended to bring the system closer to unity power factor. At the point when SVC is connected to power grid to regulate transmission voltage, then called as transmission SVC and when it is connected near large industrial loads to improve power quality, then called industrial SVC. Static var compensators have their output changed to exchange inductive or capacitive current in order to control a power system variable such as the bus voltage [14].

They have advantages over the other methods of voltage control since they contain sensors and relays which make them work automatically, it detects the state of the network, when there is low voltage, it infuses reactive power into the network to make up for power loss and when there is excess voltage, it removes reactive power, thereby bringing the voltage to the required level.

As a result of large power demanding industry advancement in central Norway, the demand in the region has expanded drastically and is required to grow further. The power import capacity to the region has already been restricted for system stability reasons. As a remedy, two SVCs were installed in the 420/300 kV grid, each rated at $-/+ 250$ Mvar. With the installation of the SVCs, the power import capacity to the region under stable conditions has increased extensively. A very large SVC was commissioned toward the end of 2007 at a key substation close to Rawlings, Maryland in USA. The installation upgrades the reliability on the 500 kV transmission systems a standout amongst the most heavily-loaded in the PJM (Pennsylvania, Jersey, Maryland) Interconnection region – by rapidly changing reactive power levels to

control the line's voltage. In addition to enhancing reliability, the SVC enables expanded transmission capacity across the PJM region. The SVC is rated at 500 kV, $-145/+575$ Mvar additionally the switching of two local 500 kV Mechanically Switched Capacitor banks (MSC). Two SVCs are in operation in the power grid in Bretagne, France, one rated at 225 kV, $-50/+100$ Mvar and the other at 225 kV, $100/+200$ Mvar. A mining complex in Peru, situated in the Andes Mountains at an elevation of more than 4.000 meters above the sea level, is a major zinc and copper producer, one of the biggest in the planet. An essential for production was the improvement of satisfactory utility infrastructure to feed the mine complex, as the feeding grid system was excessively weak, making it impossible to support the loads without legitimate measures taken. As a solution, an SVC was introduced, rated at 45 Mvar inductive to 90 Mvar capacitive. Its motivation is to stabilize the 220kV voltage at the mine feeding substation to within $\pm 5\%$, allowing safe operation of huge mining machinery even under the most prohibitive power system conditions. Western Texas, USA has an abundance of wind power. Sufficient element reactive power backing is necessary to keep up system operation at acceptable voltage levels. To enhance and keep up voltage stability, three SVCs were introduced in the system. Each SVC is rated at $-40/+50$ Mvar. Two SVCs are connected directly to 69 kV with no requirement for step-down transformers. The third is connected to the 34.5 kV tertiary winding of an existing 345/138 kV autotransformer. Each installation was first scheduled to take 11 months from the time of start to the end of commissioning. Two of the SVCs were finished in just 10 months [15].

METHODOLOGY

The method adopted is tested on two different feeders 44 and 47 buses making a total of eight five (85) buses. Dgs were placed optimally using genetic

algorithm in MATLAB and its Implementation in Etap software. Table 1 presents the results obtained as a result of the optimal placement of the Dgs.

Table 1: Summary of Results for Peak and Off Peak in the Presence of DGs.

	Peak	Off Peak
Voltage Profile	0.9202 – 0.9776pu	0.9329 -1.004pu
Active Load Demand	27.169MW	18.403MW
Reactive Load Demand	10.965Mvar	10.12Mvar
Losses (Real)	2.73MW	2.02MW
Losses (Reactive)	1.59Mvar	1.09Mvar

Etap software was also used in placing SVC optimally in the network. Table 2 presents the result obtained after the SVC has been placed in the network. In placing the SVC, three (3) buses were considered using deviation from ideal voltage profile equation (equation 2). The equipment of network and loads have been designed for operation on the ideal voltage profile (1 pu). So, operating under this voltage amplitude will increase the network efficiency and also network stability and will decrease active power loss due to decreasing current flow in the network and controlling the aggregation of reactive power in the network. Local reactive power compensation can also control the nodal voltage amplitude in the network. Static Var Compensators (SVC) should control the nodal voltage amplitude in each operating condition of the network by absorption or injection of adaptable reactive power.

$$VPI_{tot} = \sum_{n=1}^{n_{load}} \sum_l (1 - V_n^l)^2 \quad 2$$

Where VPI_{tot} is total voltage amplitude deviation of network buses from ideal voltage amplitude (1 pu). It was observed that the bus with the highest deviation of voltage profile index is the best locating point

for the SVC. This was concluded as a result of the changes in loss reduction of the load flow report.

For Otovwodo 11kV bus, voltage profile index = $4.41 \times 10^{-}$

For Dumez Road Feeder 11kV bus, voltage profile index = $2.116 \times 10^{-}$

For Isoko Road Feeder 11kV bus, voltage profile index = $1.764 \times 10^{-}$

The size of the SVC is 1MVAR and situated at Otovwodo Feeder.

Table 2: Summary of Results for Peak and Off Peak in the Presence of SVC and DGs.

	Peak	Off Peak
Voltage Profile	0.9402 – 0.9873pu	0.9502 - 1.0458pu
Active Load Demand	27.171MW	18.469MW
Reactive Load Demand	11.913Mvar	11.09Mvar
Losses (Real)	1.45MW	1.26MW
Losses (Reactive)	1.05Mvar	0.90Mvar

Fig. 4 presents the Etap software showing the placement of SVC in the presence of DGs.

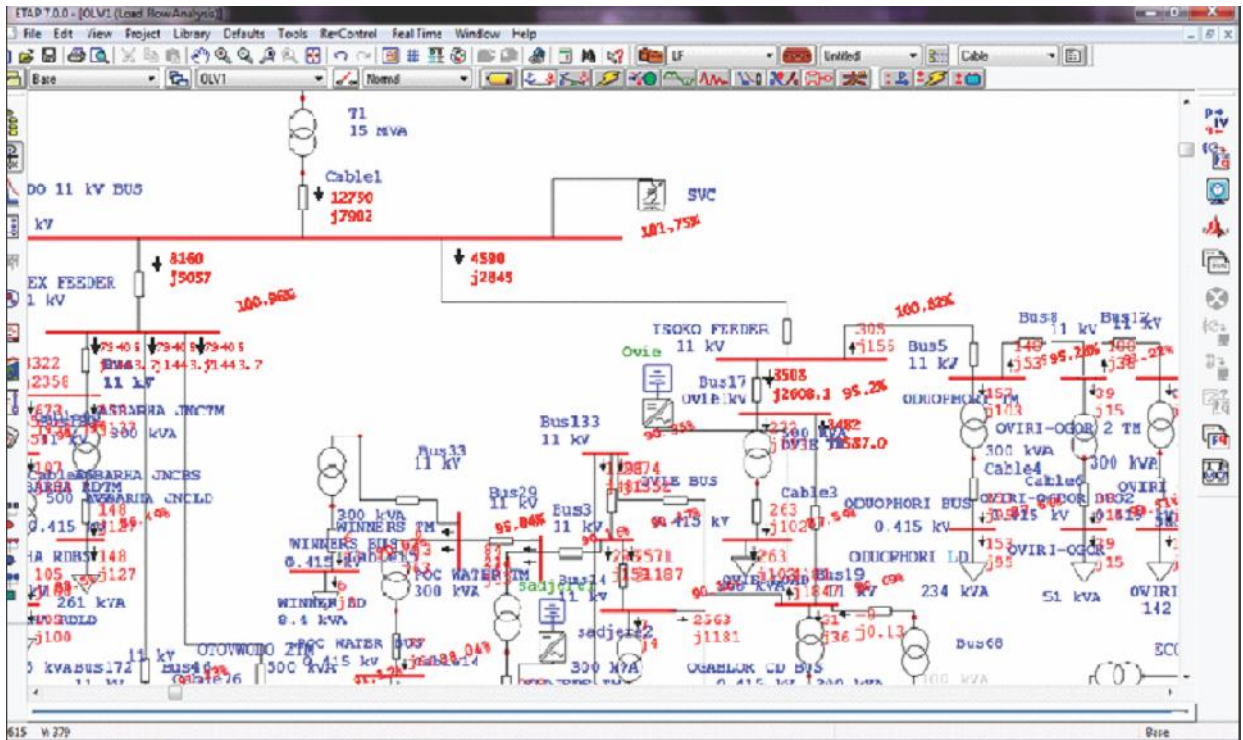


Fig. 4: ETAP 7.0 Program Showing SVC in Place with DG.

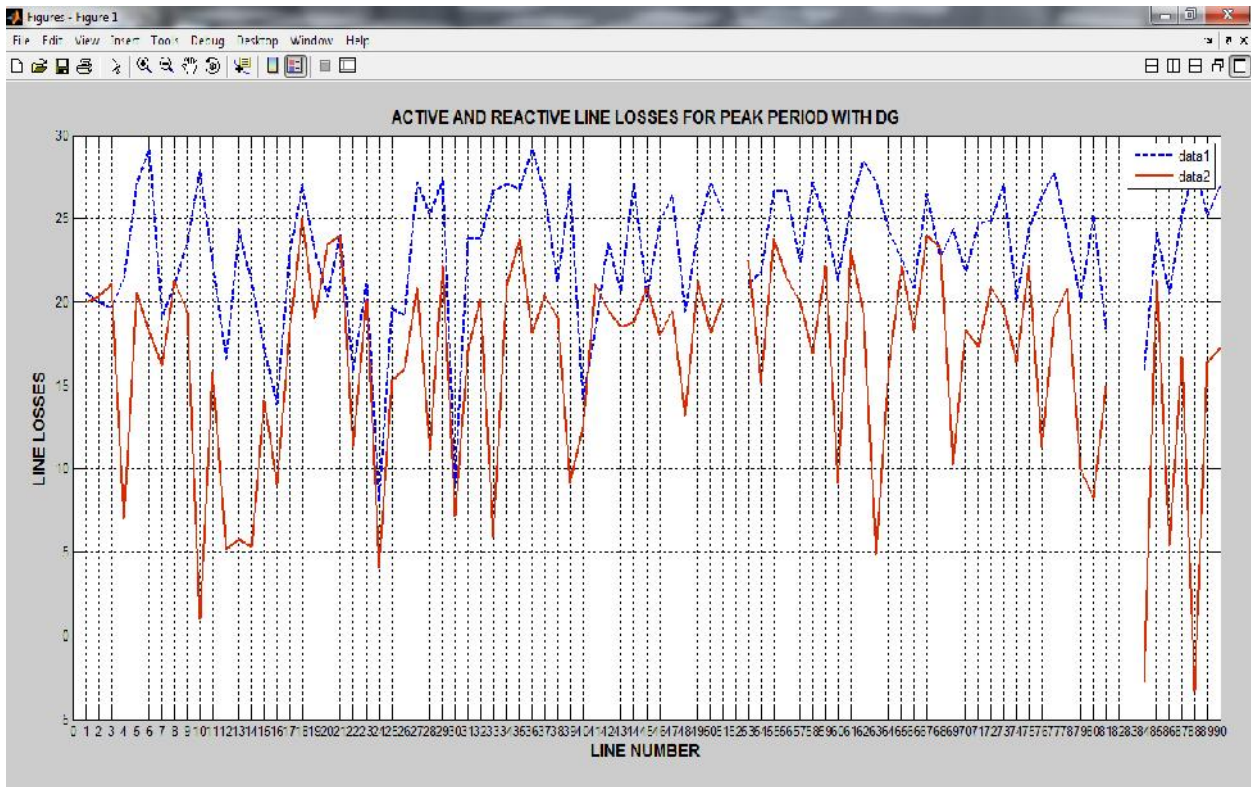


Fig. 5: Line Losses for Each Connected Bus for Peak Period.

DISCUSSION AND CONCLUSION

- When Dg was placed optimally, as presented in table 1, the voltage range during peak period was between 0.9202 – 0.9776, off peak 0.9329 – 1.004, the active load demand was 27.169MW for peak, 18.403MW for off peak, Losses in the Network was 2.73MW for peak and 2.02MW for off peak. Fig. 5 shows the graph of line losses in the network when Dgs were optimally placed.
- When Dg and SVC was placed optimally, as presented in table 2, the voltage range during peak period was between 0.9402 – 0.9873, off peak 0.9502 – 1.0458, the active load demand was 27.171MW for peak, 18.469MW for off peak, Losses in the Network was 1.45MW for peak and 1.26MW for off peak. It can be seen

from the graph in Fig.6 and Fig. 7 of line losses reduction as compared to Fig.5.

It has been shown that SVCs can improve and control voltage profile. It can also enhance power capacity and reduce losses in a distribution Network.

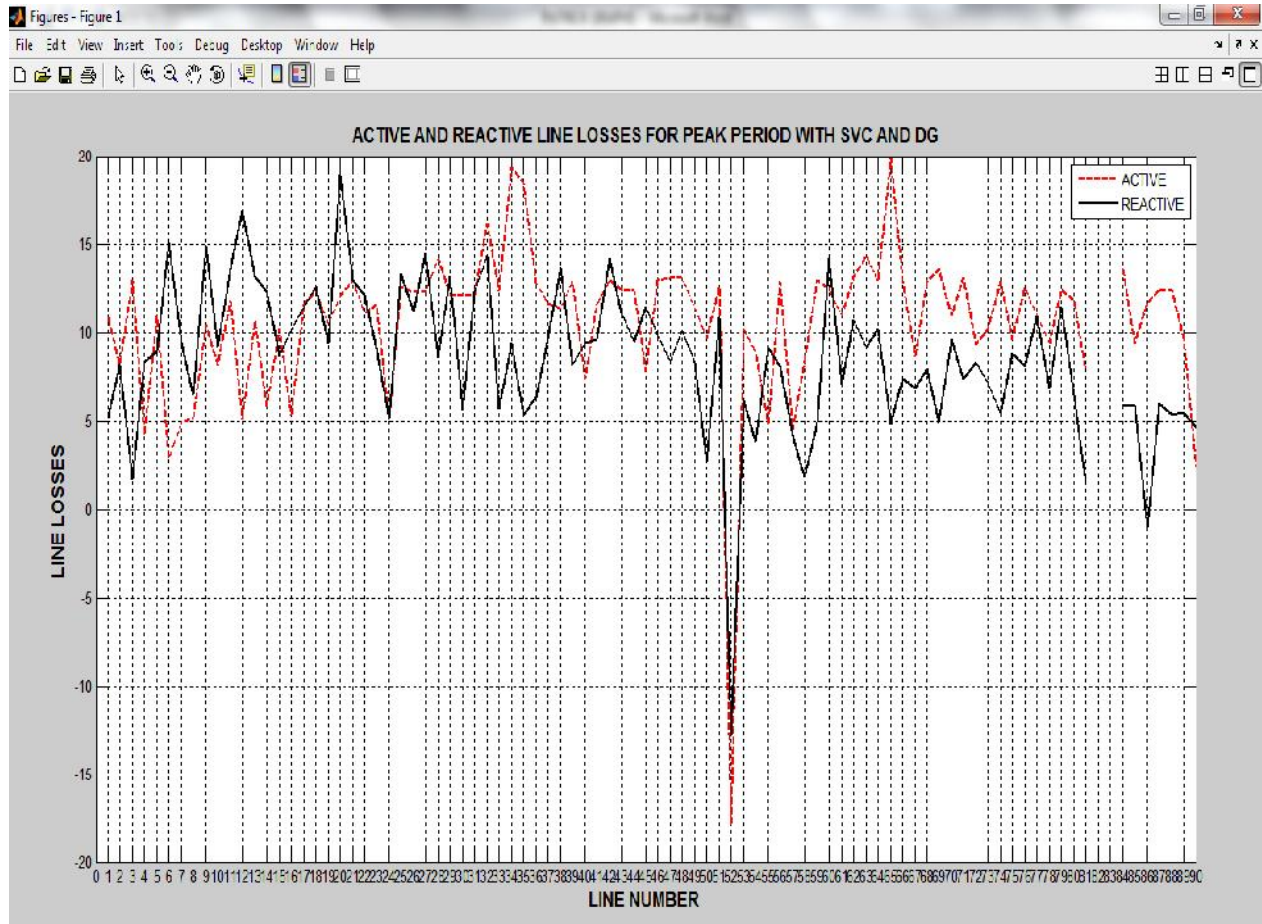


Fig. 6: Line Losses for Each Connected Bus for Peak Period in the Presence of DG and SVC.

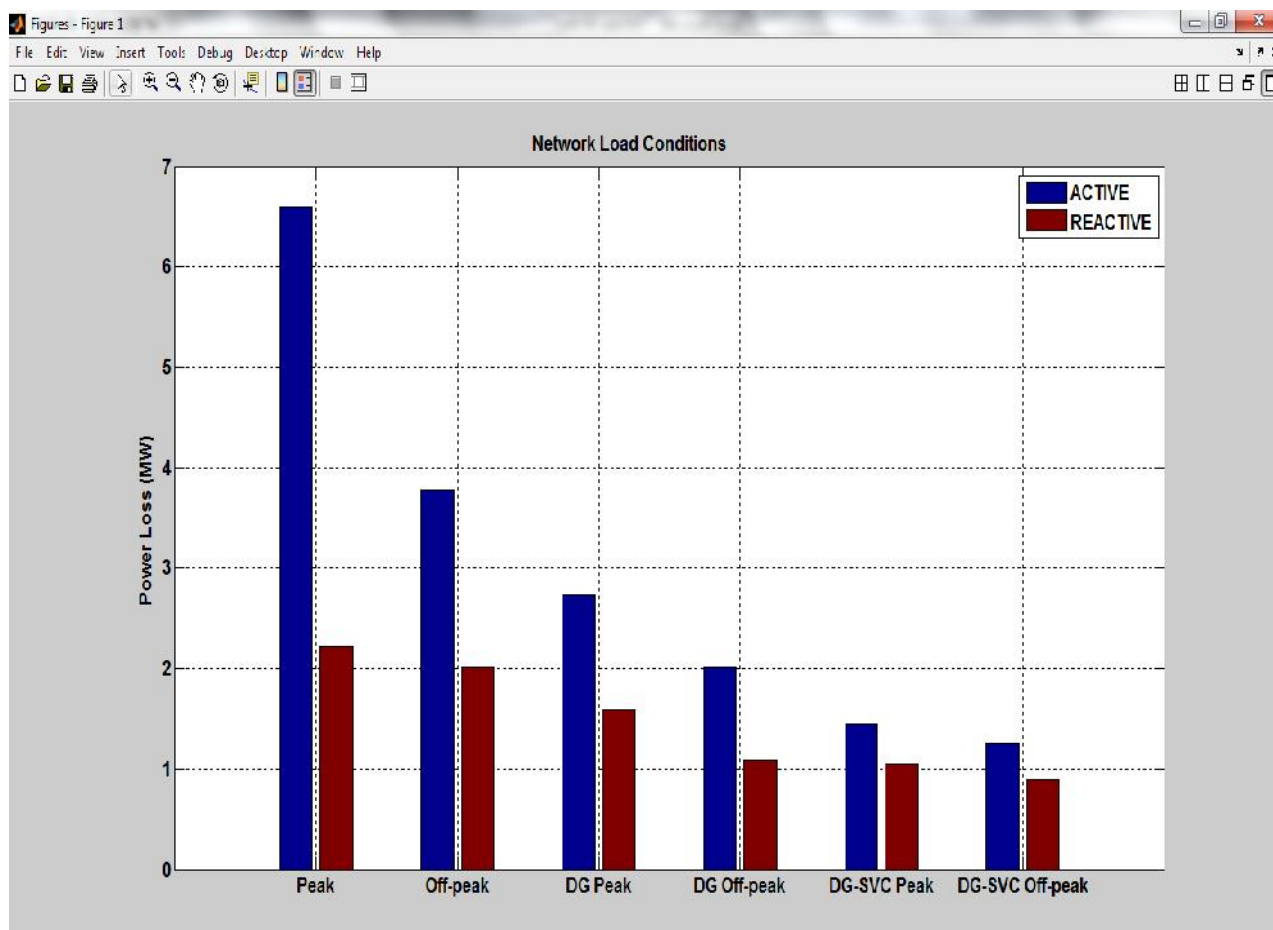


Fig. 7: Distribution Power Losses for Entire Distribution Network without DG, with DG and with DG and SVC.

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