International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 7 (2015) pp. 17181-17191

http://www.ripublication.com

# PI Control Based Power Quality Improvement Using AC Voltage Controller

**Ponraj V[1], Balasubramani M[2]**
*[1]PG-Scholar, [2]Assitant Professor,*
*Department of Electrical & Electronics Engineering, SASTRA university,thanjavur-6134001, Tamilnadu, India.*
*emai:vcponraj@gmail.com*

## Abstract

There are various trouble in the power system network to transfer power from generation point to distribution end. Current needed by a load is largely uncontrollable. To maintain the voltage fixed it is an issue making troubles that are becoming more and more important to electricity users at all levels of load usage. If sudden increase or decrease in load leads to voltage sag and swell in the power system network. Considering three area system supplied by a single generator where each phase supplies each area with single phase supply. If there is fault in any one of the line, fault may be due to phase to ground fault or sudden rise in load may lead to voltage drop so line are tripped, due to this type of problem line may get outage so there will be no supply to the particular area. This type of problem can be rectified using AC Voltage Controller. AC Voltage Controller take care of voltage sag and swell in the power system network, where sag may be created due to sudden increase in load by including faulty lined area load to the healthy line, and swell may occur due to the sudden removal of load or due to Ferranti effect. This type of problem can be rectified using AC Voltage Controller in the line. PI controllers are used to detect the voltage sag or swell in the line and appropriate gate pulse is given to the IGBT to conduct accordingly to balance the system voltage. The performance of the proposed concept of flexible voltage support control during simultaneous voltage sag and swell compensation has been evaluated by using Matlab/Simulink environment. This deals with the controlling of voltage and injecting the reactive power to the line. There is no need for multistage conversion. AC Voltage controller takes care of its own line and its neighbour line. It makes the system more stable and reliable for only single phase loaded system.

**Key Words:** AC Voltage Controller, power quality, individual phase control, voltage sag and swell, fault analysis.

## Abbreviation

| | |
|---|---|
| S1 and S2 | Switches |
| C1 | Capacitance |
| L1 | Inductor |
| Vin | Voltage Input |
| Vout | Voltage Output |
| D1,D2,D3,D4,D5,D6,D7 and D8 | Diodes |
| VL | Voltage Across the Inductor |
| Vout | Output Voltage |
| T | Total Switching Period |
| D | Duty Cycle |
| t1 and t2 | Switching Period of switch S1 and S2 |
| Vref | Reference Voltage |
| Vf | Feedback Voltage |
| g1 and g2 | Gates of IGBT |
| IGBT | Insulated gate bipolar transistor |
| AC | Alternating current |
| PI | Proportional integral |
| THD | Total harmonic distortion |

## Introduction

The electric power industry to be those part of electricity generation, transmission and distribution of power to an energy meter placed at the consumer edge. To power the load at the final stage user, electricity goes by the electrifying network. Trouble in power system network to transfer power from generation point to distribution end consumption leads to a demand, combined with fluctuation in weather condition, generation, load demand and some other causes allow lots of disturbance in quality of power to be compromised [1], [2]. Power quality is the more convenient term in favour of consumers, it is a quality of voltage instead of power or electric current. Power is determined by the flow of energy. Current needed by a load is largely uncontrollable. To maintain the voltage fixed, it is an issue making troubles that are becoming more and more important to electricity users at all levels of load usage[4], [5]. The proposed system using AC Voltage Controller is addressing the problem related to power quality. Sensitive equipment and non-linear loads are becoming ordinary in both the industries and the domestic places, due to this power quality place a major role in power systems which is explained in detail in section II. The main working principle of AC Voltage Controller is explained in section III and it's block diagram with proportional-integral (PI) controller technique is presented in the closed-loop system is discussed in section VI. The main source of problem that can disturb the power quality are: Ferranti effect, load switching, large motor starting, power electronic devices, arcing devices, embedded generation, sensitive equipment, an extreme weather condition and environment related damage, network equipment and design. The first most parameter which is affected is voltage and the next remaining problem comes. Traditionally Ferranti effect can be controlled by adding a reactor in series or removing the capacitor bank from the line. There is no need of adding or removing anything from the line with the help of AC Voltage Controller we can able to compensate the voltage swell [6] which is experimented in section V. Next major problem faced in power system is load switching, due to this imbalance in load between the phases may occurs this causes the voltage variation in-between the lines. Traditionally load flow analysis is done to analysis the active and reactive power flow in the line. By considering the AC Voltage Controller in the line real and reactive power flow can be increased which can make the voltage stable in-between the lines explained in section VI and further simulation results are discussed. AC Voltage Controllers are used to ensure the sag and swell due to the sudden change in load[8].

## Power Quality

Power quality decide the health of electric power to consumers. To operate the system in its own way Synchronization of the voltage, frequency and phase is necessary to operate without loss in performance of life. Without the desirable power, an electrical load are not adequate to operate properly it might lead to malfunction, go wrong permanently or won't work. There are various way in which electric power can be of poor quality. Adding up new transmission system is an almost an unimaginable and impossible solution due to several environmental and other condition in power system operation and control. Power quality improvement using AC Voltage Controller with the fundamental concept of independent control of active and reactive power flow extends an alternative for achieving the objectives. This controller extends a great opportunity to determine the transmission of alternating current which leads in increasing or decreasing power flow in particular lines and responsible for instantaneous stability problems. AC Voltage Controller provides control on one or more AC transmission line and gain in the capacity of power transfer. A network with a bad power quality, it leads to system failure or reduced in the lifetime, and the efficiency of the electrical equipment which is installed in the power system network will reduce.

## AC Voltage Controller Principle and Its Operation

The Fig. 1 shows the basic circuit pattern proposed converter. This circuit has the following feature: it can able to function in a single phase line and regulate the output from voltage sag or voltage swell in the power system network. The input voltage of this device is not necessary it can operate at any voltage (until the IGBT is capable) and it can stabilise the output voltage considerably. As a result, it is more suitable for developing countries because economically too fit for them. This circuit simplifies and the cost of the transmission line is reduced. Filter circuit consisting of inductor L1 and a capacitor C1 as shown in Fig. 1. The switch S1 and S2 are bi-directional. It is a two insulated gate bipolar transistors (IGBT). The IGBT has internal anti-parallel diodes which allow for the freewheeling current path when the reverse voltage happens. Inductor L1 is used both to store and transfer the energy to the output side.

Inductor L1 is connected and disconnected to the supply with a regular interval by switch S1 this regulates the power delivered to the inductor. When the switch S1 is off position then the stored energy of the inductance L1 provides a freewheeling path since the inductor current to discharge. The switch S1 and S2 works in a complementary mode. The switch S1 and S2 can't be switched on simultaneously.

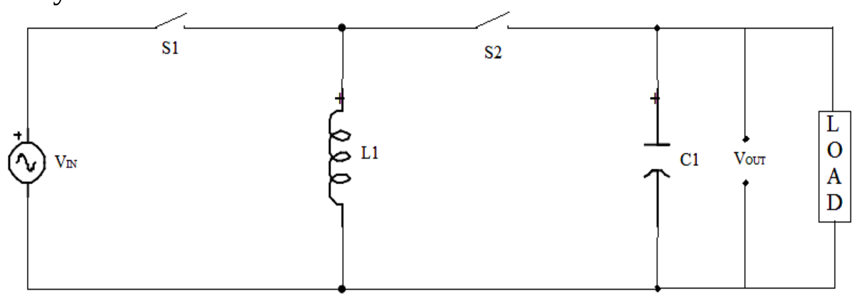


**Figure 1:** Single Phase AC Voltage Controller

**Analysis of Buck Boost AC Voltage Controller**

For our better understanding analyzing the single phase AC Voltage Controller with two single phase bidirectional switches. There are two mode(mode 1 and mode 2) of operation and two-cycle(positive cycle and negative cycle) of operation. Each mode and cycle of operation is explained bellow.

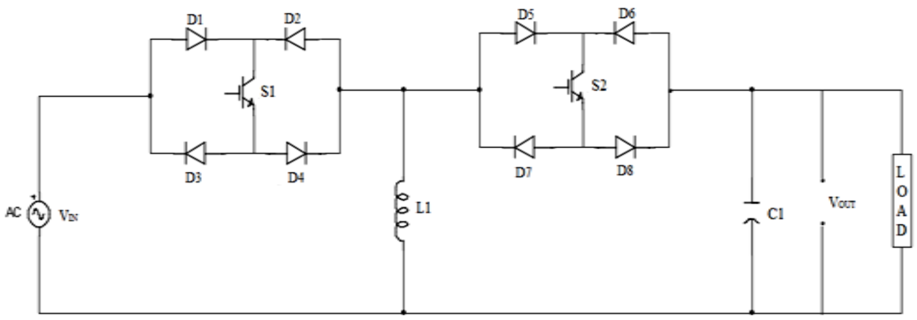


**Figure 2:** AC Voltage Controller With Diode Conduction

**Mode 1: Positive Cycle Operation**

In mode 1 operation switch S1 is in "on" condition and switch S2 is in "off" condition, During this condition diodes D1 and D4 starts conducting thus the current flows from D1 to S1 and S1 to D4 and the inductor L1 gets charged. Even though, diodes D5 and D8 are in closed position switch S2 is not in "on" position so it won't conduct.

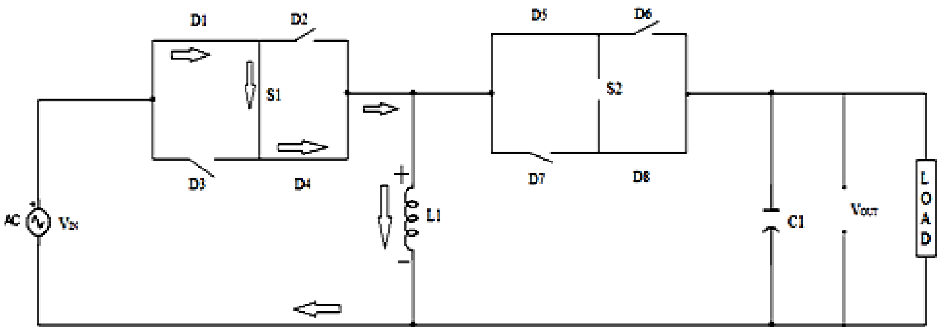


**Figure 3:** AC Voltage Controller In Mode 1 Positive Cycle Operation

Applying KVL around the loop, we get

$$v_{IN}= v_L \tag{1}$$

where $v_L$=voltage across the inductor

**Mode 2: Positive Cycle Operation**

In mode 2 operation switch S2 is in "on" condition and switch S1 is in "off" condition, During this condition inductor L1 starts discharging through diodes D7 and D6 start conducting thus the current flows from C1 to D6 and S2 to D7 and the current direction gets reversed due to discharge of the inductor. The polarity in the load side gets reversed as shown in the figure. Even though diodes are in closed position the switch S1 is in the "off" position so it won't conduct.

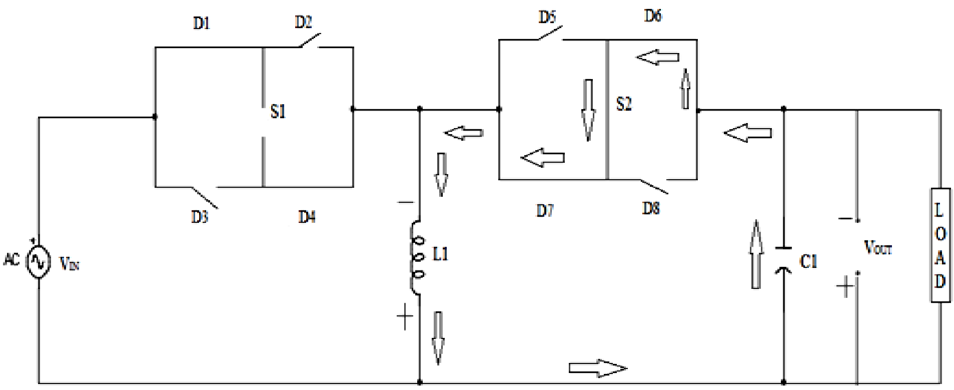


**Figure 4:** AC Voltage Controller In Mode 2 Positive Cycle Operation

Applying KVL across the loop we get

$$v_L=v_{OUT} \tag{2}$$

The switching period,

$$T=t1+t2 \tag{3}$$

The duty cycle of the controller

$$D=\frac{t1}{T} \tag{4}$$

The duty cycle's complement is

$$(1\text{-}D) = \frac{t2}{T} \tag{5}$$

Very small switching period of time is considered when compared to the AC hertz in steady state, In one switching cycle all the inductors average voltage should be equal to zero, and this can be conveyed as:

$$v_L = D(v_{IN}) + (1\text{-}D)\,(v_{OUT}) = 0 \tag{6}$$

The above equation can be written as

$$(1\text{-}D)\,(v_{OUT}) = -\,D(v_{IN}) \tag{7}$$

At finally the ideal relationship of the time-varying instant output voltage can be conveyed in terms of output and the input with the duty cycle as

$$(v_{OUT}) = \frac{-D}{(1-D)}\,(v_{IN}) \tag{8}$$

From the above equation, AC Voltage Controller can able to operate in both step up and step downing of voltage at the output level. The output voltage is in opposite polarity from the source voltage in AC voltage controller. The output voltage of the controller will be less than input voltage when the duty cycle D is less than 0.5. When the duty cycle is more than 0.5, the output voltage of the converter will be higher than the input voltage. Similarly for mode 1 negative cycle operation and mode 2 negative cycle operation.

## AC Voltage Controller In Power System Network

The Fig. 5 shows the AC voltage source where it comes from the power plant and it is connected to the grid using the bus bar then the power is transmitted to a long distance and then it is distributed, during transmission there may be sag or swell in voltage it can be corrected using AC Voltage Controller which is used in between the bus bars or even at the distribution end. Voltage drops which occur not only due to transmission loss it also occurs due to the sudden change in load so using this AC Voltage Controller can maintain the voltage in between the tolerance limit. Filter circuits are used to reduce the harmonics in the line and also used to inject the reactive power to the line. PI Control topology is used to control the gate signal of IGBT. Where Vref is the reference voltage and Vf is the feedback voltage.

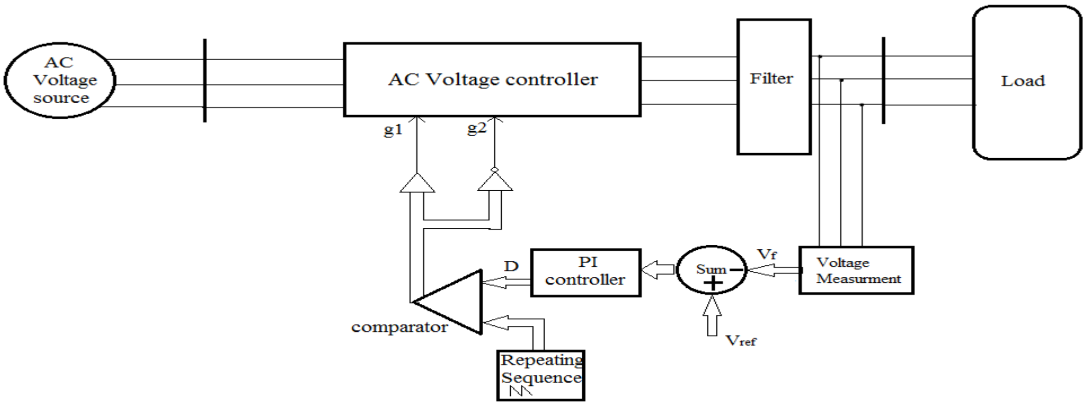


**Figure 5:** AC Voltage Controller Block Diagram

## Ferranti Effect In The Line

A Large amount of charging current is absorbed in the long transmission line. When these lines are open circuited or lightly loaded at distribution end under this condition receiving end voltage will be greater than sending end voltage is known as Ferranti effect. This type of problem can be rectified using AC Voltage Controller in the line. Using this AC Voltage Controller at the distribution end by adjusting the firing angle of the switches can control the voltage in the line. Increased in receiving end voltage is created using removal of large load from the system in the simulation at 0.1 time instant, until 0 to 0.1 second loads are equally distributed and the voltage is maintained almost constant in all phases. After 0.1 second there is an large removal of load in any one of the phase so that there is an increase in voltage in that particular line this can be compensated using AC Voltage Controller, after 0.2 second AC Voltage Controller starts its control action and the system voltage is maintained almost constant which is shown in the Fig. 6.

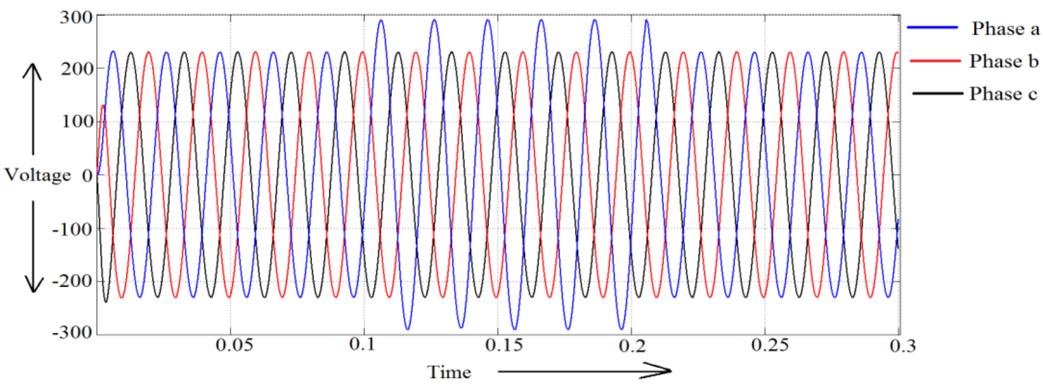


**Figure 6:** AC Voltage Controller Under Ferranti Effect

**AC Voltage Controller In Distribution End**

Considering a three phase line where each phase is connected to a three different areas with a single phase supply. If the AC Voltage Controller kept in all the three lines then there is no problem in distribution because AC Voltage Controller takes care of voltage sag and swell due to sudden variation in load. If it is not economically feasible to erect AC Voltage Controller in each line in developing countries then our idea comes, with the use of any one single phase AC Voltage Controller can able to maintain all the three or more area loads if there is any outage in the other line.

If there is a fault in any one of the line. The fault may be due to phase to ground fault or sudden rise in load may lead to tripping off the line, due to this type of problem line may get outage. There is an alternate solution to solve this kind of problem in the power system network, that is, faulty line should be isolated first and then connect the load to the isolated line to another line where AC Voltage Controller is fixed because it takes care of voltage sage and swell and also inject the reactive power to the line by using the filter circuits. By erecting this type of arrangement, this can able to give an uninterrupted power supply to the customer. PI controllers are used to detect the voltage sag or swell in the line and appropriate gate pulse is given to the IGBT to conduct accordingly to balance the system voltage. The performance of the proposed concept of flexible voltage support control during simultaneous voltage sag and swell compensation has been evaluated by using Matlab/Simulink environment as shown in Fig. 7.

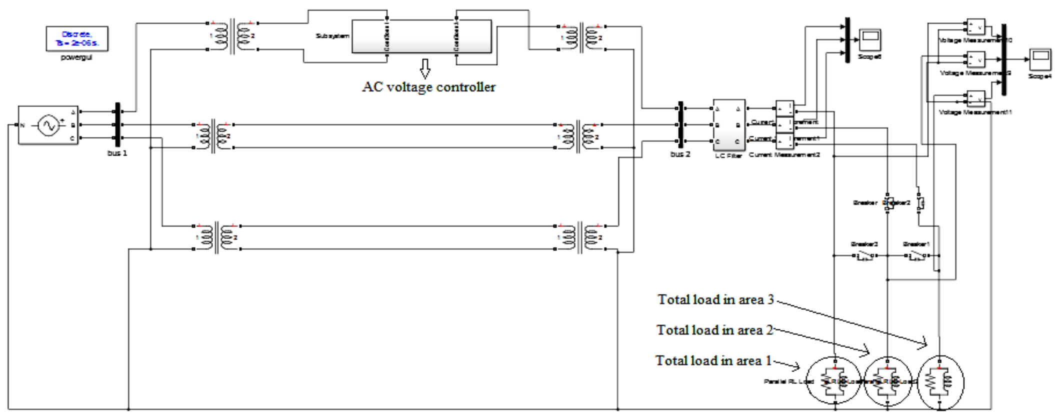


**Figure 7:** AC Voltage Controller In Matlab Simulation

## Simulation Results and Discussion

Three area loads(area 1, area 2, area 3) are connected to an three phase programmable source supply with an phase 'a', phase 'b', phase 'c, where AC Voltage Controller erected in one of the lines considering at phase 'a' line. Until 0.1 second three-phase are equally distributed to the line loads. Considering a fault accurse in phase 'c' (faults are created using circuit breakers) at an time 0.1 seconds at the same instant an another circuit breaker connects the faulty line load to the healthy phase at phase 'b'.

Even considering the fault occurs in phase 'b' at 0.2 seconds then there is only one line (phase 'a) which is healthy. In normal power system network total loads in area 2 and 3 can't be connected to the healthy line because it may also get affected due to large load in the line, but using the AC Voltage Controller in any one of the line (phase 'a') can able deliver the system voltage even though there is voltage sag in the line due to heavy load. For our better visual graph fault exist for an period of 0.2 second to 0.3 second after 0.3 second AC Voltage Controller is triggered to control the voltage sag in the line as shown in the Fig. 8 Even it can be connected to the three phase load where if there is any fault in any one or two of the phases, with an single phase supply the entire system can able run the three phase supply by introducing a special arrangement called phase shifting circuits in between the phases and then three-phase load is connected to the system.

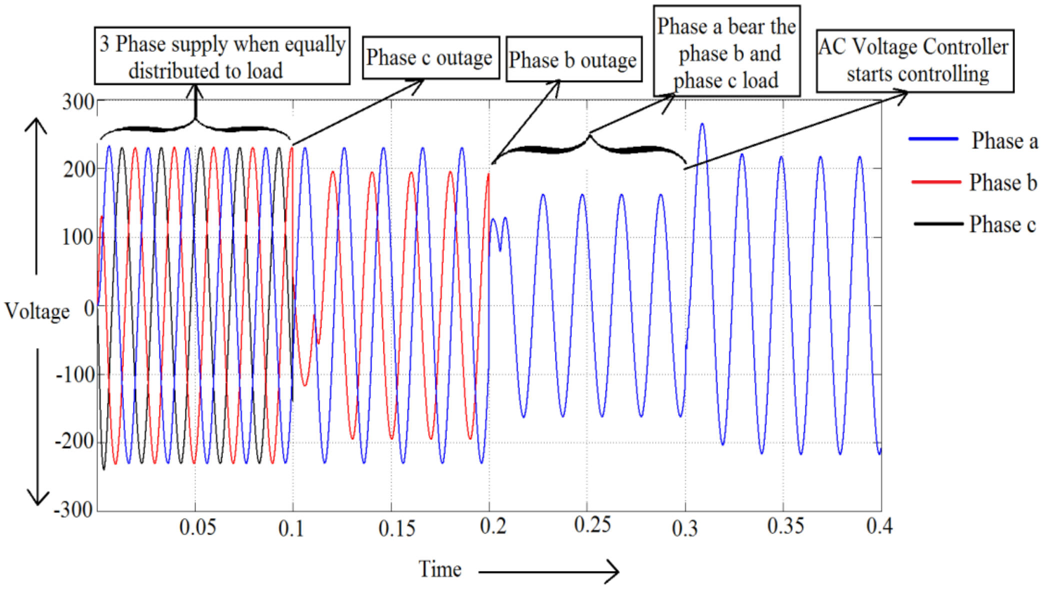


**Figure 8:** Output Voltage With And Without Fault

Currents are equally distributed in the 3 phase line as shown in Fig. 9 from 0 to 0.1second. After 0.1 second fault occurs in phase 'c' so the phase 'c' is isolated from the line and its load is connected to the phase 'b' so the current in the phase 'b' increases from 0.1 to 0.2 seconds. Even phase 'b' gets faulted at 0.2 seconds and it's total load(area 1, area 2, area 3) is connected to the phase 'a'. until 0.2 to 0.3 seconds faults are not rectified for our better graphical representation. After 0.3 second AC Voltage Controller stars controlling the voltage sag and also injects the reactive power flow in the line to maintain the voltage within the tolerable limits.

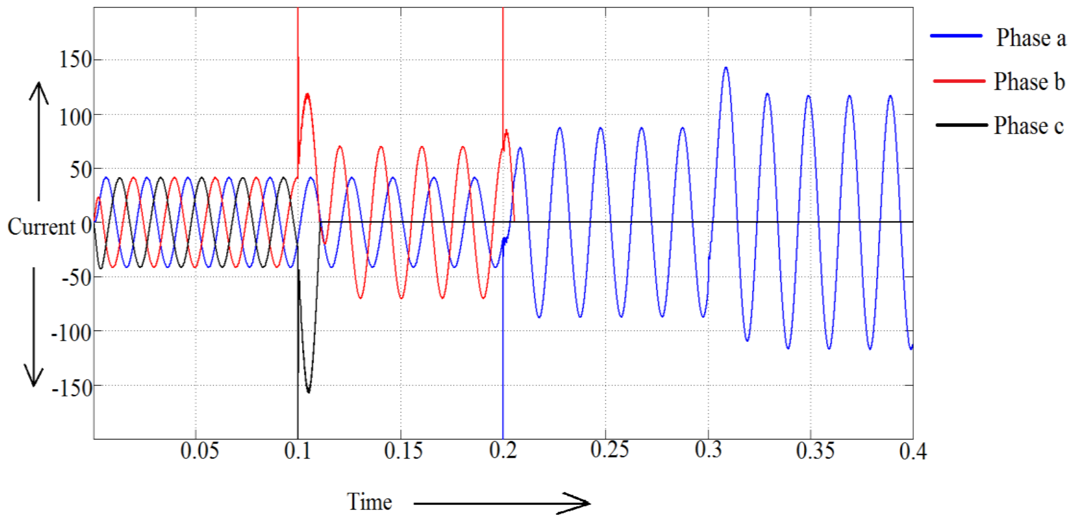


**Figure 9:** Output Current With And Without Fault

## Total Harmonic Distortion (THD)

At fault clearing time, there is a slight oscillation in voltage after clearing the fault the system voltage is maintained constant.

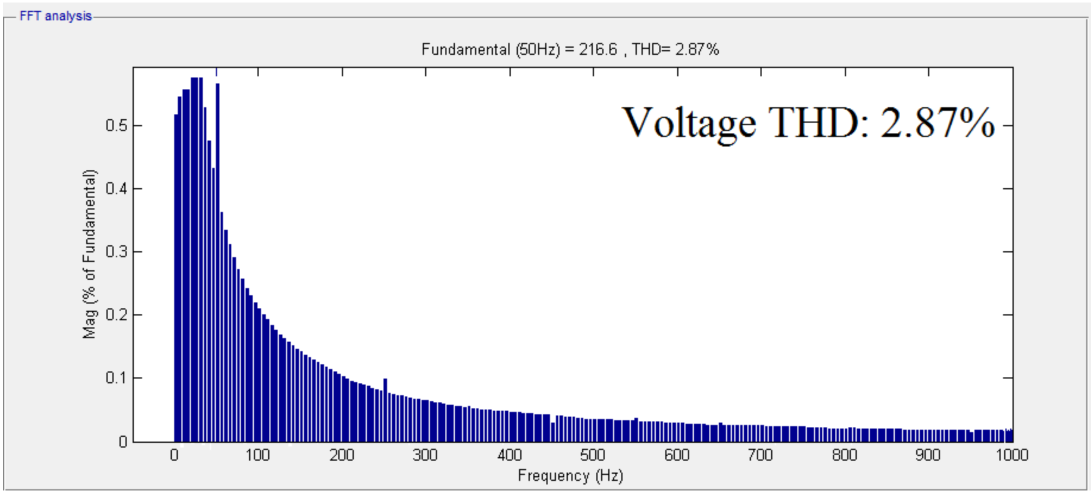


**Figure 10:** Output Voltage Harmonic Distortion (THD)

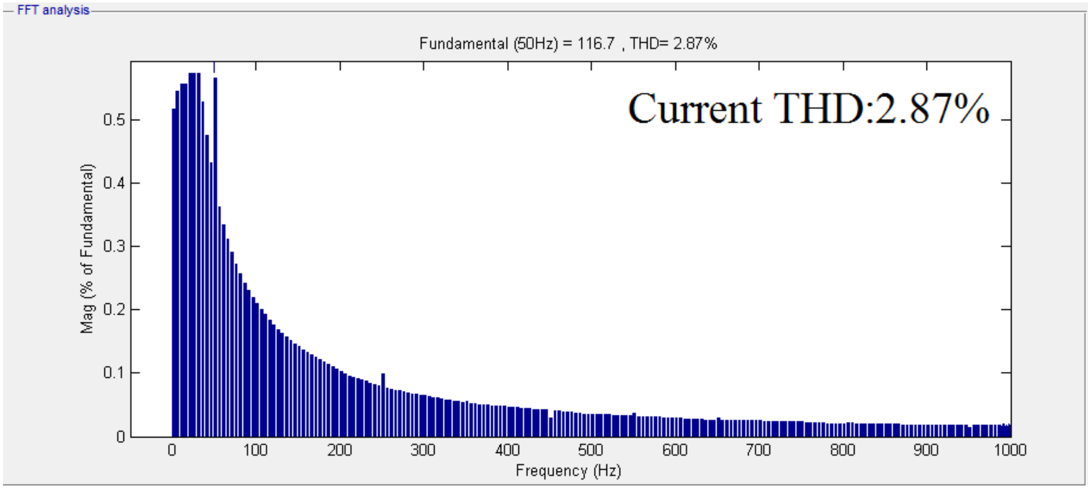


**Figure 11:** Output Current Harmonic Distortion (THD)

## Conclusion

This paper has proposed the method for flexible voltage support control of distribution network by fault analysis. Voltage sag and swells are created in the three phase system where voltage sag is created using sudden load switching and the voltage swell is created due to line charging current it is corrected using AC Voltage Controller. Where considering three area distribution system with a single generator supplying the entire loads. By creating a faults on the line came to an conclusion that single phase supply can able to deliver three individual phase loaded areas, with a design methodology of cascaded proportional-integral (PI) controller technique, is presented in the closed-loop system.

## References

[1] Narain G.Hingorani, 2000,"Understanding FACTS Concepts And Technology Of Flexible AC Transmission Systems", 1st ed., IEEE Press Producer, New York.

[2] Rahman, M, November 1997,"UPFC Application on the AEP System: Planning Considerations." IEEE Trans. on Power Systems, 12, (4).

[3] C. Schalkwyk, H.J. Beukes, H.T. Mouton, 2002,"An AC to AC Converter Based Voltage Regulator" IEEE Africon, pp. 719-722.

[4] N. Vazquez, A. Velazquez, C. Hernandez, 4-7 June 2007 "AC Voltage Regulator Based on the AC-AC Buck-Boost Converter", in Proc. of IEEE Int. Symp. on Industrial Electronics (ISIE 2007), pp. 533–537.

[5] F. Z. Peng, L. Chen, and F. Zhang, 2003,"Simple topologies of PWM AC-AC converters", IEEE Power Electronics Letters, 1(1) pp. 10–13.