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# Power Quality Enhancement in Distribution System using Dynamic Voltage Restorer

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***Abstract*—**The applications of Power quality at industrial and commercial scale is very important to be assured for the customer. But due to some reasons the load power system destructed like Sags of voltage, destruction of harmonics, irregularity in the voltage waveform and transient. Sensitive devices of power may also be harshly effected by voltage sags and change in the harmonics. Due to increase the heat in the power system devices and electrodes problem of harmonics could occur that may lead to failure of different speed drives and spin pulses in motors. The necessary requirement in the power system is decrease in harmonics. The use of DVR (Dynamic Voltage Restorer) in the power system devices is the source of reduction of this problem. To overcome the disturbance of voltage Sag and harmonics, it is the efficient and economical solution. Reduction of Total Harmonic Distortion (THD) will increase the quality performance of power system. Dynamic Voltage Restorer is used in this paper. Reduction in % THD and voltage sag are successfully corrected by using DVR on MATLAB/SIMULINK Software Package.

***Keywords*—**Dynamic Voltage Restorer (DVR), Total Harmonics Distortion (THD), voltage source inverter, Voltage sag.

## I. INTRODUCTION

Nowadays industrial devices are typically based on the electronic devices such as PLC, microprocessors, computer, adjustable speed drives and inductive loads are very sensitive to disturbances such as voltage sag, swells and harmonics. Total harmonic distortion or THD of the signal is the measurement of the harmonic distortion present and is defined as the ratio of the sum of power of all harmonic components to the power of the fundamental frequency. THD is used to characterize the linearity of the audio system sent the power quality of the electrical system.

Harmonics have frequencies that have integer multiples of the waveform's fundamental frequency. For example, given a 50Hz fundamental waveform, the 2nd, 3rd, 4th, and 5th harmonic components will be the 100Hz, 150Hz, 200Hz and 250Hz respectively.

Thus harmonic distortion is the degree to which a waveform deviates from its pure sinusoidal values as a result of the summation of all these harmonics elements. Power quality problems have focused much attention in recent years as voltage sag is widely recognized as the most severe problem to the industrial loads affecting the power quality and performance [1].

THD is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave.

$$THD = \frac{\sqrt{(V2 + V3 + V4 + \cdots)}}{V1} X\ 100\%$$

The formula shows the calculation offer THD on a voltage signal. The end result is the percentage comparing the harmonics components to the fundamental component of the signal. The higher the percentage, the more distortion that is present on the main signal.

Voltage sag depends upon the duration and the magnitude of the rms voltage. Voltage total harmonic distortion plays an important role in a power system to maintain its quality and according to IEEE 519-1992 standards, total harmonic distortion should be equal or less than 5.0% of the fundamental frequency. IEEE standard 1152-1995 defines the sags root mean square (RMS) voltage variation with a magnitude between 0.1 pu and 0.9 pu of nominal voltage and duration typically ranging from a 0.5 second to sixty seconds. This voltage sag can cause undesirable function of the industrial machines and can eventually shutdown of machines, resulting in substantial productivity losses. By installing a custom power device, voltage mitigation or compensation can be achieved to reduce or cancel out the disturbances at the load end [2].

The usage of sensitive devices in chemical plants could effected by the drop of voltage and swell of voltage that leads to stoppage and failure of system. Because of these problems in the system the problem of tripping of breakers and blow fuses may occur with the disturbance of high currents. The interruption in the system and damage of equipment takes high cost from customers due to the various changes in the quality of system [3, 4]. The use of voltage sags is important in the common circulation systems rather than increase in voltage. The stimulation of big capacitor and switching off of a big inductive load is the main reason of voltage swells [5].

The sensitive devices are much vulnerable to small variations in the voltage that are due to severe change in the voltage sags. The changes in the magnitude of voltage supply in the phase shift is not the cause of voltage sags in the system. When the value of voltage become low there are changings that not remain permanent and get back to original position. By the failure of circuit and energization of transformer the resultant voltage become decreases as the short-term variation cause the generation of voltage sags on line. The serious destruction of widespread variety of devices is due to these short-term changes in the system [6].

The extent of voltages at the time of sags and interval could decide the specification of voltage sags. In practical way, the production duration of voltage sags is not much harming as the after the production loss may occur due to voltage sags. The problems of manufacturing lost, destruction of device, fear of breakage and restarting again could cost millions of dollars to be repaired because of voltage sags [7].

There are various custom power devices obtainable each with its own limitations and advantages for voltage reduction compensation such as DSTATCOM, SMES, DVR and SVC. DVR is a controlled voltage source inserted in between the network and a sensitive load voltage through a transformer inserting voltage into the distribution line to accurate any disturbance disturbing the sensitive load voltage. DVR with lead acid battery is a finest and attractive technique to deliver excellent dynamic voltage mitigation capability as compared to shunt connected devices. The main function in the power system is voltage source inverter with DVR to inject the desire three phase voltage to the load [4-5].

## II. Existing Secondary Distribution Network Implementations & Results

Power quality in distribution system is very important in commercial and industrial applications. The paper is basically for a specific case (A well-known public sector mechanical industry). We have taken one of the inductive load i.e. L_NF1 load and added the three phase fault at the 11kv feeder line to analyze the behavior in the distribution system as shown in Table I.

Unfortunately, sudden faults occur in power system which create disturbance and affect the Load voltage form are sags, transient, total harmonic distortions and notching. Out of these sag voltage and harmonics have severe impact on sensitive devices. Total harmonic distortion i.e. 6.29%, 9.61% and 6.54% on L_NF1 load in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors. Reduction of harmonics is considered desirable.

TABLE I. ACTUAL NFS SHOP LOAD OF HMC INDUSTRY

NFS SHOP

| S.No | Load | KW | KVA | KVAR |
|---|---|---|---|---|
| 1 | L_NF1 | 55 | 71.42857 | 45.57456 |
| 2 | L_NF2 | 45 | 65.21739 | 47.20496 |
| 3 | L_NF3 | 50 | 73.52941 | 53.91266 |
| 4 | L_NF4 | 55 | 78.57143 | 56.11122 |
| 5 | L_NF5 | 90 | 120 | 79.37254 |
| 6 | L_NF6 | 110 | 139.2405 | 85.36931 |

The figure 1 shows the three phase existing distribution system with NFS load. The 11KV, 50Hz three phase supply is step down 11kV/380V. The Three phase fault has been applied at 11kv feeder line to create a voltage sag and the fault resistance is 50 ohm. The voltage sag event has occurred on the 11kv feeder line for a period of 0.05 to 0.185 sec, the fault has reduced the three phase non-ferrous load voltage from 300 peak voltage to 124.1v, 125.8 and 133.2 which can disturb the L_NF1 load may cause system failure .In addition, the total harmonic distortion (THD) has increased to 6.29%, 9.61% and 6.54% due to voltage sag [8-9].

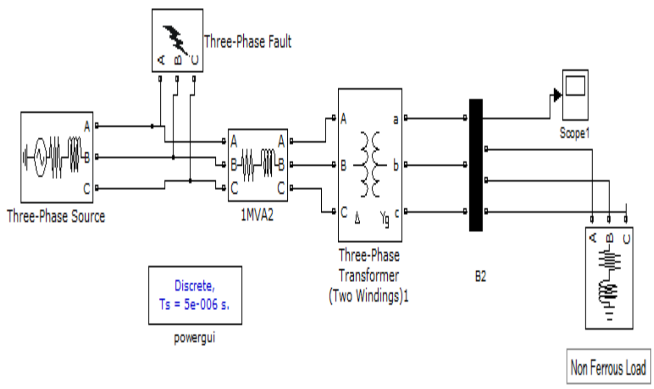


Figure 1 Simulation of Three phase Distribution system

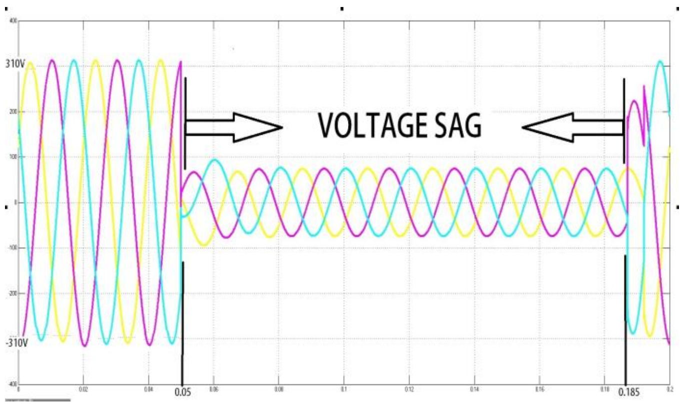


Figure 1.1 Load Voltage during Fault without DVR

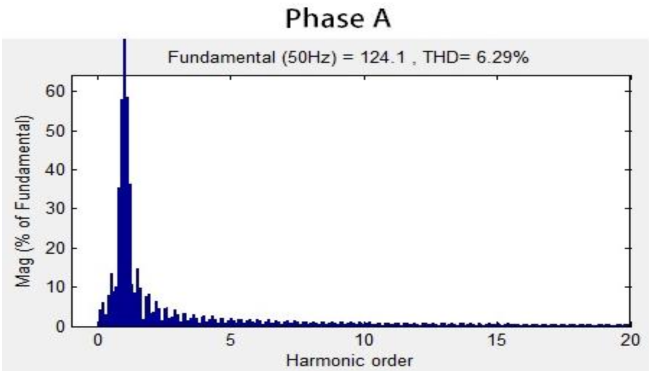


Figure 1.3(A) % THD during fault on L_NF1 Load

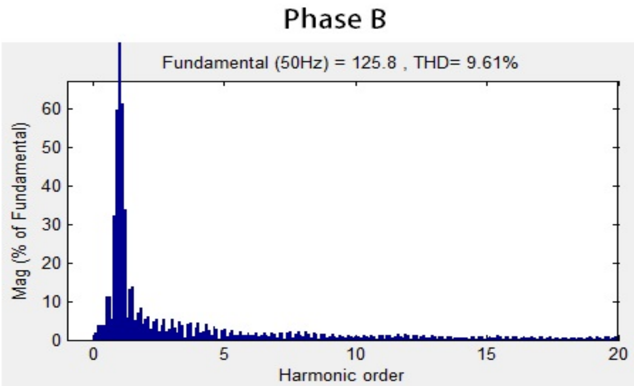


Figure 1.3(B) % THD during fault on L_NF1 Load

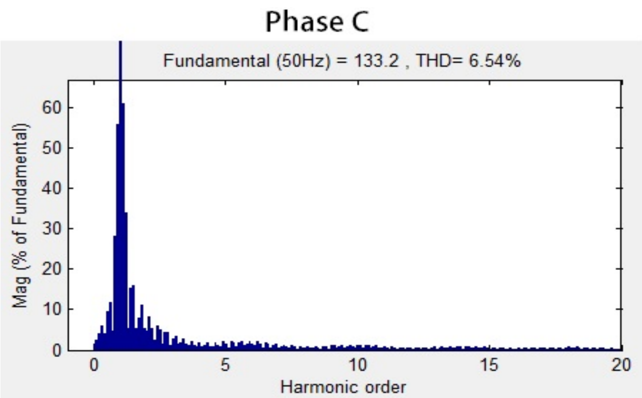


Figure 1.3(C) % THD during fault on L_NF1 Load

## III. PROPOSED SECONDARY DISTRIBUTION NETWORK IMPLEMENTATION & RESULTS

Generally, DVR is used to transmit the voltages for the compensation as a necessary method in the DC side in which inverter is the source of transformation of value to the injected transformer before the filter. The fundamental role of DVR in the existence voltage sag is to add the values that are missing in the cycle by using a bunch of injection transformer. At the time of disturbance by voltage sag 3-phase injection voltage is the source of mitigation of this problem at secondary supply by means of amplitude of power. The defense of turbulences in the AC secondary source system through the voltages of various varieties done by production of voltages of identical values by means of inverter. The ejection of same voltages at the intermediate values of voltage done by using the faster transformer [8]. The mandatory parameters are shown in the Table II .

TABLE II. PROPOSED SECONDARY DISTRIBUTION NETWORK WITH DVR PARAMETER

| S.No | Parameters | Values |
|---|---|---|
| 1. | Source Supply Voltage | 3.00-Phase 11.1kv,50Hz |
| 2. | Injection transformer Turn ratio | 1:1, 380/380v |
| 3. | Inductive Load | 55KW, 47KW |
| 4. | Invertor | Carrier.Frequency = 1080.00, Sample.time = 20-6 |
| 5. | Filter inductance and resistance | 1 ohm, 200-6 |
| 6. | Battery Voltage | 1K |
| 7. | Three Phase Fault Resistance | 50ohm |

Figure 2 shows that we have proposed the DVR which is coupled in series with the inductive load. There are two bus bars i.e. B1 and B2 and these bus bars are used for measuring input and voltage output. DVR control unit is monitoring the input and output voltage continuously via bus bar to prevent the system from any bad event. In addition, to test the performance of the DVR, the behavior of the system is examine at 11kv feeder line by adding 3-phase fault block. The 3-phases system having voltage sags of simulation with range 0.05 to 0.185 seconds. We have seen that the voltage sag event has been occurred. At this scenario, the DVR responded very well and corrected the voltage sag problem in millisecond.

Figure 2.1 is showing the injection voltages has been added at the distribution side. The inductive load is joint with the injection transformer and within the step-down transformer. PWM is the suitable way for the DVR in the existence of voltage sags to put voltage injection.

At voltage peak range the inductive load will be controlled and the mitigation of disturbance of voltages fully is elaborated in figure 2.2. The addition of total harmonic distortion percentages (THDV) as component of DVR cause the change in the voltage as shown in figure 2.3.

Furthermore, figure 2 showing the both uncompensated and compensated systems. Through the influence of variation in the storage means of power and energy cause load voltage's unsettling influence of total harmonics. The scope of capacity of energy at optimal level select the value such as 1000v showed the precise working ability of energy source. For both devastations, like existing harmonics and compensate voltage sags DVR is suitable to mitigate them in the resultant study. In conclusion, the objectives of DVR in the system to remove the harmonics issue fully from the load side and has been maintenance achieved [10-11].

The presented system in the study showed the similarity of both series of active power filters and the equivalent circuit of the DVR. Hence, DVR could give flawless and quick transient reply like power filter use to di by not regulating any additional necessities.

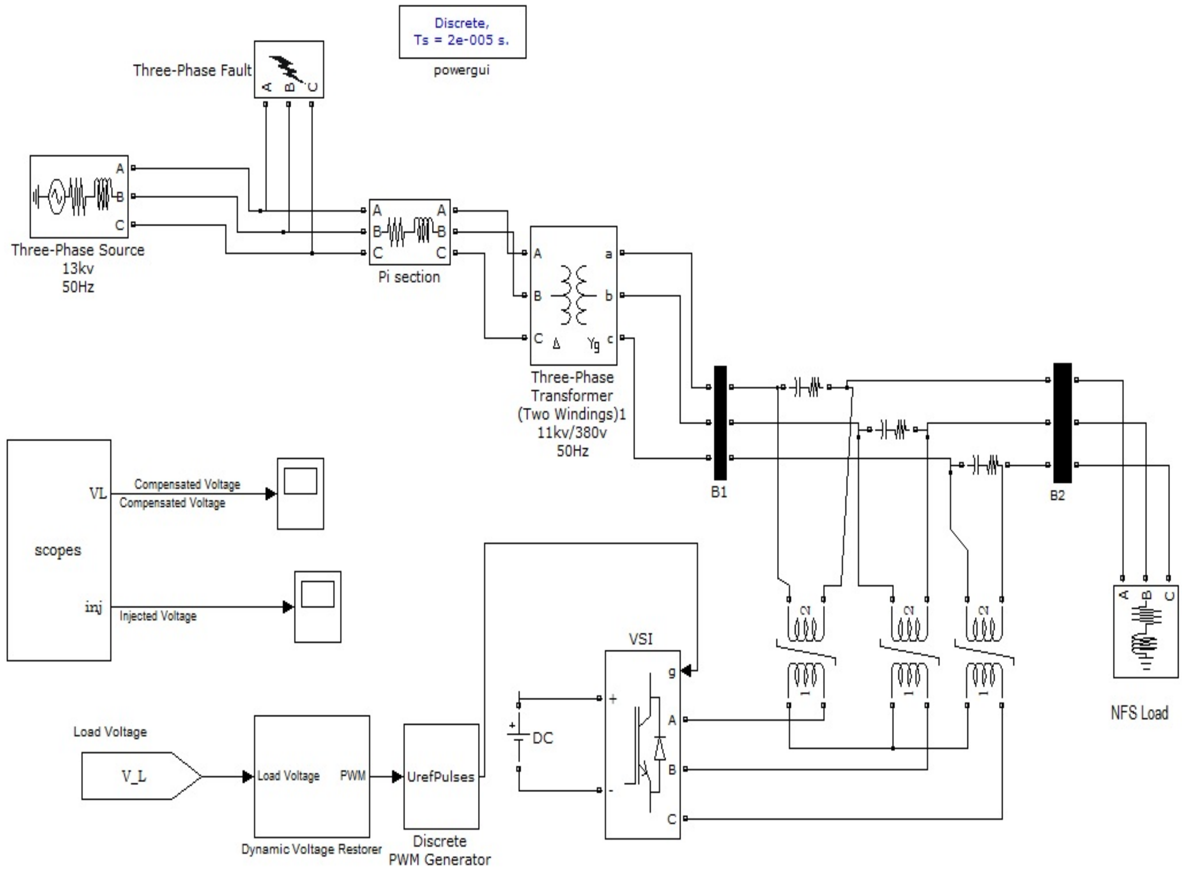


Figure 2 Proposed Secondary Distribution Network with DVR Circuit Diagram

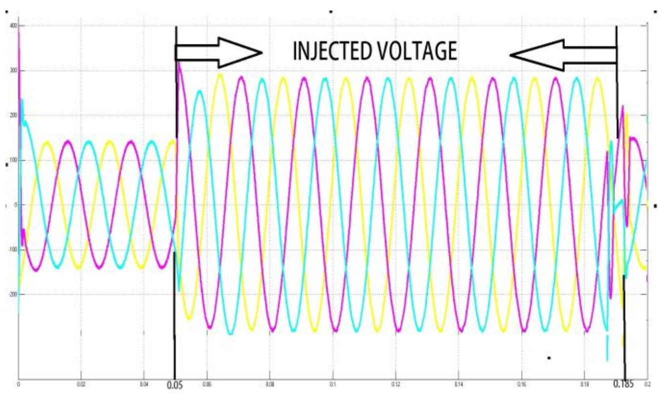


Figure 2.1 Injected Voltage via Injection Transformer in Secondary distribution Network

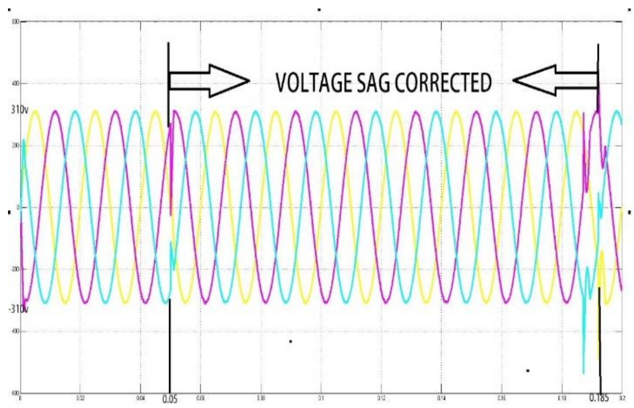


Figure 2.2 After Compensation (Sensitive Load Votlage)

The disturbance of Harmonics distortion removed in the end results of simulation model by using DVR. As shown in figure 2.3(A), 2.3(B) & 2.3(C) to reduce the harmonic distortions in 3-phase system FFT analysis is used.

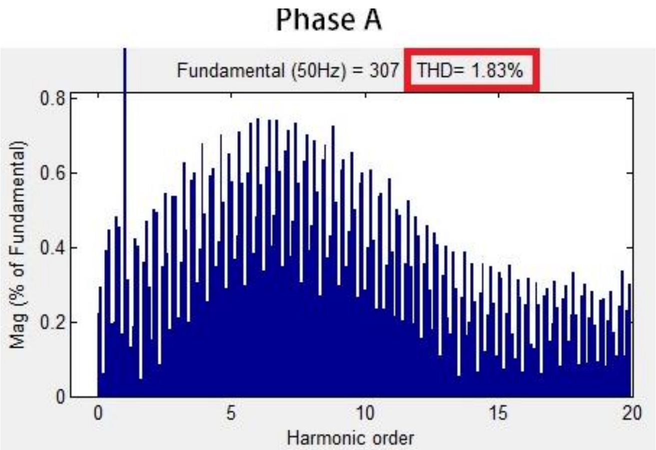


Figure 2.3(A) FFT analysis of the sensitive load voltage with DVR

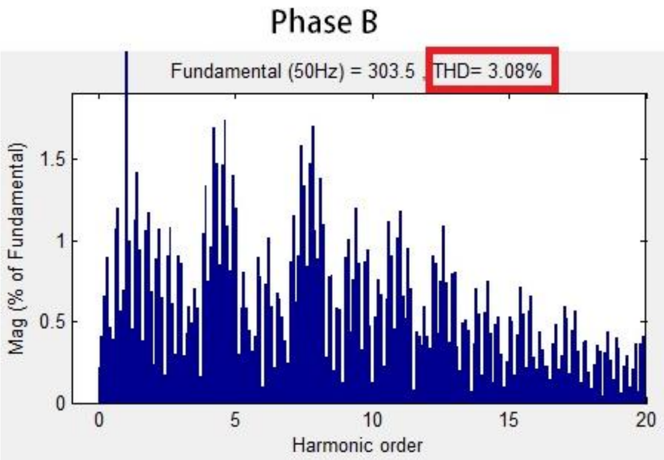


Figure 2.3(B) FFT analysis of the sensitive load voltage with DVR

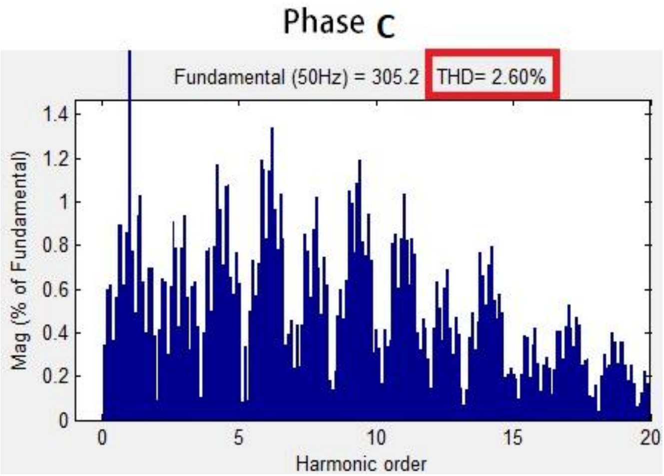


Figure 2.3(C) FFT analysis of the sensitive load voltage with DVR

## IV. Existing & Proposed Secondary Distribution Network Comparison

Within the time 0.051 - 0.1851 sec a 50 Ω fault is embedded by utilizing 11.11kv feeder as a fault of 3.00-phase secondary distribution network for a short period of time, this faulty condition is achieved first when no DVR was exist in the framework When there is no DVR put into the system and the voltage range of load point of 100V is dependent on 310V supply then %age of THD increased in the presence of voltage sag. After the joining of DVR in the arrangement of second reenactment the system is same as examined above with the entire disposal of voltage droops. The upkeep of rms voltage at the load scope of 310v with the markdown in the issues at rate THD with DVR framework is appeared in figure 2.4. By utilizing MATLAB for the reduction or compensation of voltage swells/sags to enhance compel, Dynamic Voltage Restorer (DVR) is predicted and made. The proposed framework is beneficial system to repay the issues of voltage sags and THD in almost no time seconds for example milliseconds as emerge from the present arrangement of MATLAB in which the high range reduction of THD present in the structure has been finished [12-13].

To manufacture the nearness time of structure and to moderate the stinging conditions the delicate weight sides utilized the skilled proposed framework.

TABLE III. Without Compensation & With Compensation (Sensitive Load THD)

| S.No | Secondary Three Phase Paramters | Without Compensation. THD% | With Compensation THD% |
|---|---|---|---|
| 1 | Phase(A) | 6.29% | 1.83% |
| 2 | Phase(B) | 9.61% | 3.08% |
| 3 | Phase(C) | 6.54% | 2.60% |

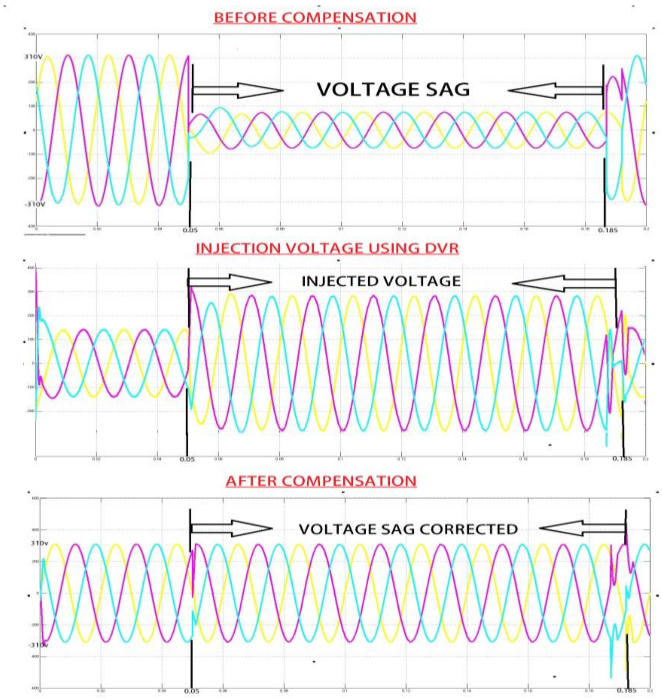


Figure 2.4 Without Compensation and with Compensation (Inductive Load)

## V. SCOPE OF WORK

This Paper is on total harmonic distortion due to the production of voltage sag in one of the most industrious public-sector of Pakistan. The distribution system in the commercial and industrial applications are much imperative in terms of power quality. To analyze the behavior in the distribution system, the addition of the 3-phase fault at the 11kv feeder line and inductive load of L_NF1 load was taken.

Unfortunately, there are following disturbances to the load voltage including sags, transient, total harmonic distortions and notching that create unexpected faults in power system. The sensitive devices are most vulnerable to these voltage sag and harmonics. The failure of various speed drives and spin pulses in motors occur due to the hormonic distortion on L_NF1 load as a result of increase in the heat of power system. The power system should solve the problem of harmonics [14].

To overcome this problem, proposed Dynamic Voltage Restorer (DVR) has been used in the existing test system. It is an economic and effective solution for the protection of sensitive loads from harmonics and sags. In this paper, modeling, analysis and simulation of DVR has been used to enhance the performance of DVR by reducing Total Harmonic Distortion (THD). By using DVR on MATLAB/SIMULINK Software Package the percentage reduction of THD and voltage sag become successful [15].

## CONCLUSION & FUTURE WORK

To proceed with the typical estimation of voltage for looking the viability of DVR to controller the load a supply of voltages infused in the present voltage sags mutilations, 3-staged framework that created voltage sags in variable conditions of the time space of DVR reproduction process. In conclusion, the DVR prove to be an effective system to remove the harmonics and voltage sags issues for simulation model. In the assumption the DVR is an efficient system to accurately restore the voltage of 310V in the presence of voltage sag. This projected system is easy and cost effective. It is nothing else but DVR.

Moreover, in future, the proposed system DVR can be improved using PID, Fuzzy Logic and SMC controllers can be used to get optimal values so that we can enhance efficiency of the Dynamic voltage restorer to mitigate the THD.

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