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MITIGATION ON POWER QUALITY DISTURBANCES IN POWER SYSTEM USING ELECTRONIC CONTROLLER

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ABSTRACT

Recently an outsized interest has been focused on power quality domain due to disturbances caused by the non-linear loads, Increase within the number of electronic devices and growth of renewable energy sources. Power quality measures the efficiency of electrical power transmitted from generation to the economic, domestic and commercial consumers. A minimum 50% of power quality problems are of voltage quality type. During a power grid voltage sags and voltage distortion introduced by harmonics are considered to be the foremost severe affecting power quality, due to both utilities and consumers are suffering from these disturbances. These problems might be solved by design equipment's and electrical systems to stop electrical disturbances from causing equipment's or systems to malfunction, Analyze the symptoms of an influence quality problems to work out its causes and solutions, study the medium that's transmitting the electrical phenomenon and eliminate or reduce the effect of that medium, Treat the symptoms of the facility quality problems by using the facility conditioning device and custom power device. This paper presents the facility quality problems like , sags, swells, harmonics, voltage interruptions and transient and therefore the paper presents power quality enhancement techniques which are two categories power conditioning devices and custom power devices the second method is that the most effective and effective method to unravel the facility quality problems and protective the sensitive loads from power disturbances. During this paper, the modeling and simulation of an influence distribution system was achieved using MATLABL/Simulink. Three phase fault and double line to ground fault are created with the proposed system, and therefore the faults are initiated at duration of 0.8sec till 0.95sec. Comparison the facility quality problems with and without custom power device are presented. Dynamic Voltage Restorer (DVR) is employed to treat the facility quality problems.

Keywords: DVR,SAG,SWELL, PEECH

INTRODUCTION

Electrical power is that the main element that required in any function within the commercial and industrial sectors therefore it should be available in the least times. Power quality may be a set of parameters that outline the characteristics of the facility supply as delivered to the consumers in normal operating conditions in terms of continuity of supply and characteristics of voltage like, frequency, magnitude, waveform and symmetry. Recently, power quality isn't only a technical problem but also a drag that results in financial issues. Many surveys are shown that poor power quality causes large economic losses to industrial sectors. Moreover, great deal of power is wasted thanks to poor power quality within the services. A survey conducted to assess economic impact of poor power quality faced by Various Indian industries by Emerson group and manufacturers' association for information technology (MAIT) states the estimated loss in India is on the brink of 10 Billion USD in direct losses thanks to poor power quality and operating environment associated with downtime. Awareness among the industries regarding the facility quality should be created which helps within the increase in productivity and Gross Domestic Product (GDP) growth. PQ events are unpredictable but they will be anticipated. Determining the precise problems requires sophisticated electronic equipment but the symptoms like breakdown during lightning and thunder storm, tripping of circuit breakers without being overloaded, automated system stopping for no apparent reason, electronic system failure on a frequent basis and also working of electronic system in one location but not in another location, help us to spot the PQ problems [1]. The facility quality is Gaining importance from the subsequent reasons: power electronic devices and developed equipment with microprocessor based controls are more sensitive to power quality variations; the utilization of power electronic devices based control of variable speed drives and switched mode power supplies creates tons of electrical disturbances into the availability system [1]. The statistical aspects of the facility quality problems as identified variety of surveys are shown in fig.1. From this figure the foremost common causes of disturbances at customer's side are: Faulty equipment and Improper grounding to guard against surge, while the foremost common disturbances at utility side are caused by: Sags and swell and therefore the commonest affected equipments are: Computers and UP.

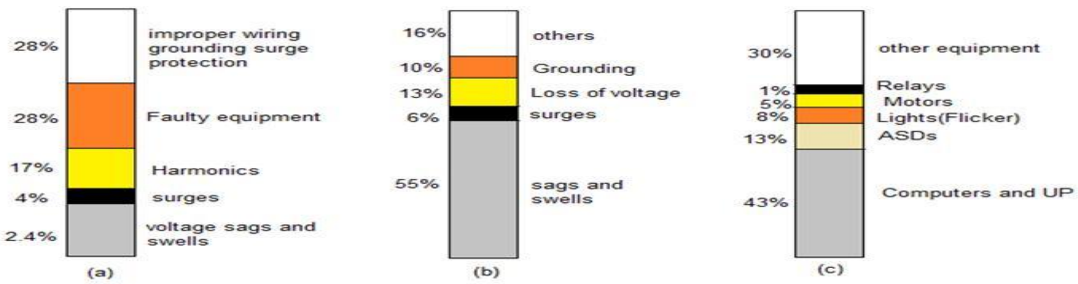

Fig.1 Basic disturbances: (a) Causes at customer side.

(b) Causes at utility side. (c) Affected equipment

A large number of equipments that consists of power electronics devices are employed by the economic, commercial and residential customers at their installations, these equipments are sensitive to power quality disturbances. The studies and therefore the surveys in several countries round the world are noticed that industries are susceptible to reliability issue (long and short interruptions). The Voltage sag is that the main power quality problem for the manufacturing industries and telecom sectors. Harmonics problems are perceived especially by the service sectors like hospitals and banks. In [2,3] another survey has been shown that the most problem For the continuation of industries are: loss of synchronization of processing devices, the tripping of relays and contactors without overloading and damaged computers and electronics devices. Also it's been noticed that the most problems of the facility quality disturbances in commission and transport sectors are: breaker, damaged electronics equipments and Lights flicker, blink or dim of these surveys are shown within the Fig.2.

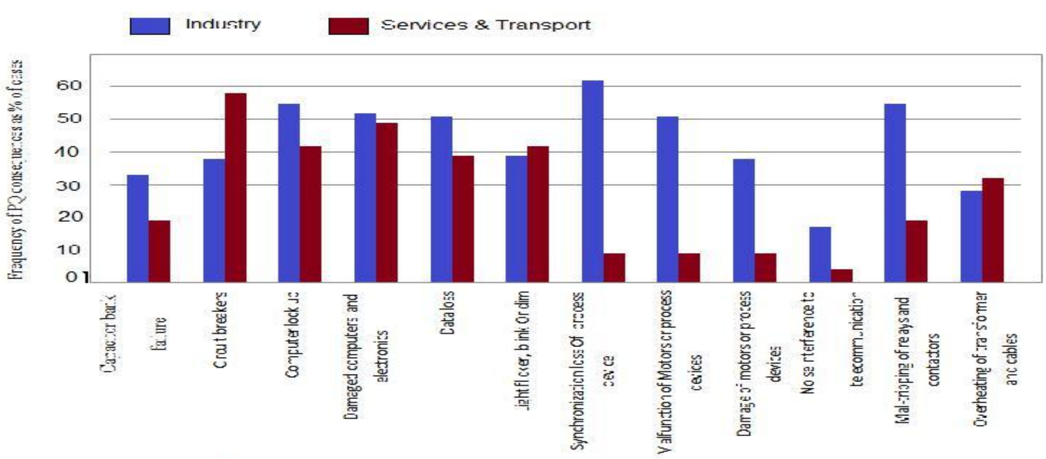

Fig.2 Consequences of poor PQ as experienced by the customers [3,4]

2-Classification of power quality problem power quality may be a combination of voltage and current quality. In most cases the utility is liable for voltage quality at the purpose of common coupling (PCC) while the consumers often influence the present quality at the PCC[4,5]. There's always a relationship between the voltage and therefore the current in any practical power system [6]. Consistent with the IEEE definitions from IEEE standard 1159-1995[7] fig.3 shown the demarcation of varied power quality problems of transmission line.

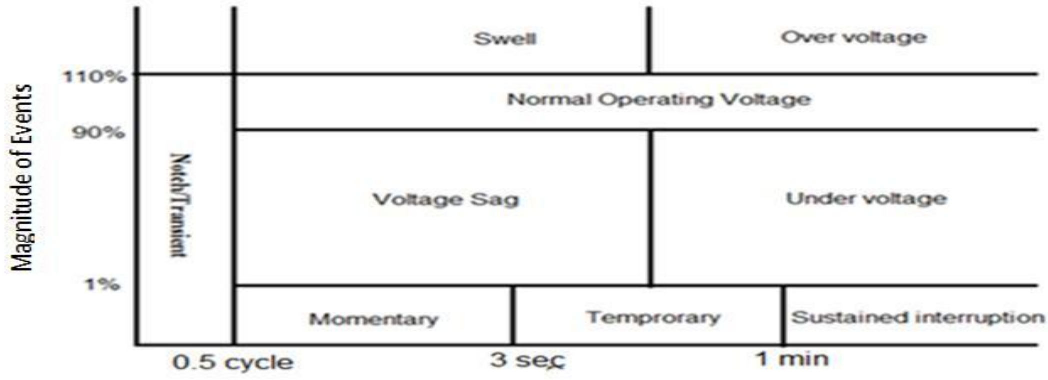

Fig.3 Voltage disturbances

Another survey is shown in fig.4 we will conclude from this figure that the voltage sag, harmonics and asymmetrical voltage are the foremost common power quality problems within the process .

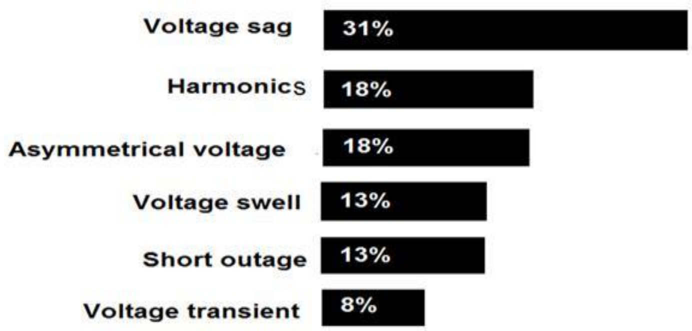

Fig.4 Power quality problems classification

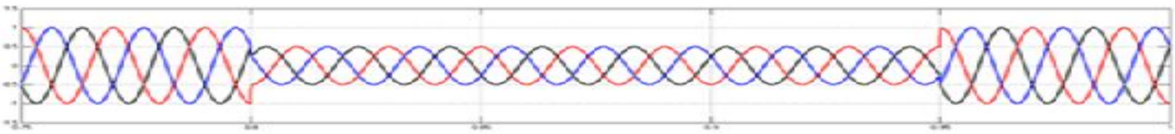

Fig.5 Symmetrical sag caused by three line to ground fault

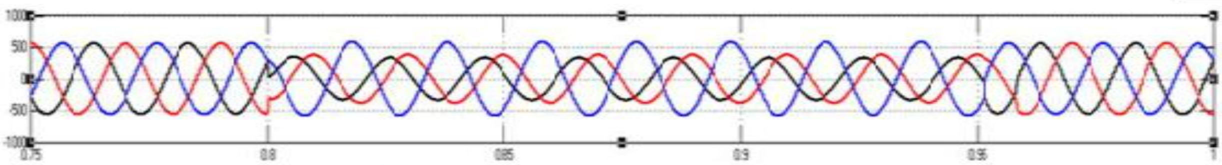

Fig.6 unsymmetrical voltage sag caused by double line to ground fault

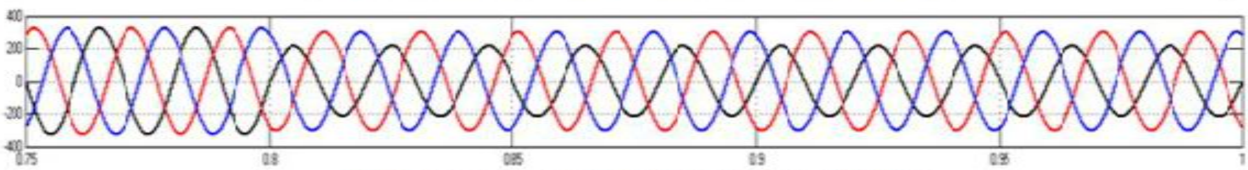

Fig.7 Unsymmetrical sag caused by single line to ground fault

POWER QUALITY PROBLEMS

i) Voltage sags:

A voltage sag is a sudden decrease in the rms voltage that the voltage value become between 0.1 and 0.9 pu from its nominal value, and lasting from 0.5 cycle to several seconds. Sags with duration of less than a 0.5 cycle are considered as transients. Voltage sag either symmetrical or unsymmetrical as shown in figures.5,6,7.

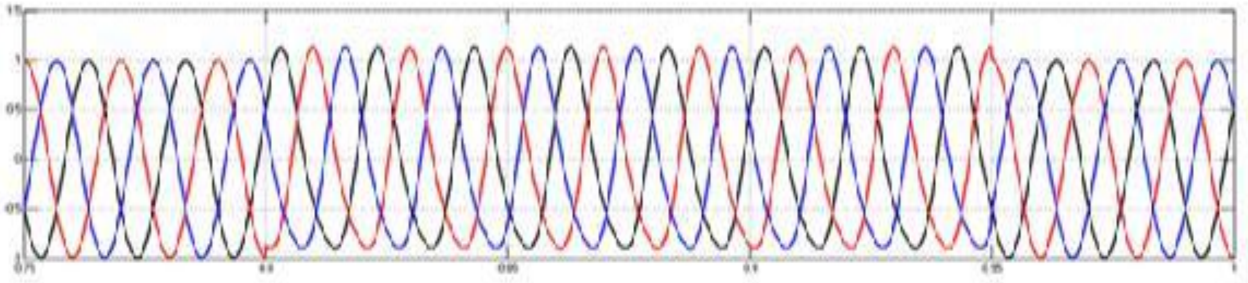

Fig.8 Voltage harmonics

ii)Harmonics

Harmonics are often defined because the spectral components at frequencies that are integer multiples of the elemental frequency. fig.6 2nd order and 3rd order harmonics are presence with the elemental frequency waveform. it's distorted as shown in Fig.6 The main cause to harmonic voltage distortion is that the nonlinear loads. Also There are several factors that contributing to the voltage harmonics and distortion such as:

- The voltage generated by a synchronous machine isn't exactly sinusoidal thanks to small deviations from the perfect shape of the machine.
- The power grid transmitting the electricity from the generation stations to the load isn't completely linear. for instance is that the power transformer, where the non-linearity is thanks to saturation of the magnetic flux within the iron core of the transformer.
- Modren example of a non-linear power grid component is that the high voltage DC (HVDC) link. The transformation from AC to DC and back takes place by using power-electronics components which only conduct during a part of a cycle of operation system.

The most common harmonic current drawn non-linear loads are all single and three phase power converters which contain rectifiers such as DC motor drives, Adjustable speed drives (ASD), Uninterruptable Power Supplies (UPS), Switched mode power supplies (SMPS), fluorescent lighting, electrical heating furnaces, welding machine, arc furnaces. Besides these non-linear loads, AC generator, AC motors and transformers also produce harmonic currents. The effects of harmonics include harmonic heating and torque pulsation . These effects ultimately result in damage to the equipment. Transformers and other industrial equipment are more susceptible to harmonic Harmonics voltage distortion can lead to control errors and malfunction of equipment. This can especially be a big problem in industrial power systems, where there is a large concentration of distorting load as well as sensitive load[10].

iii) Swell: A voltage swell is a sudden increase in the rms voltage between 1.1 and 1.9 pu at the point in the electrical system, and lasting for 0.5 cycle to several seconds. Swells with duration of less than a cycle are regarded as transients.Fig.9 shows a waveform depicting a voltage swell

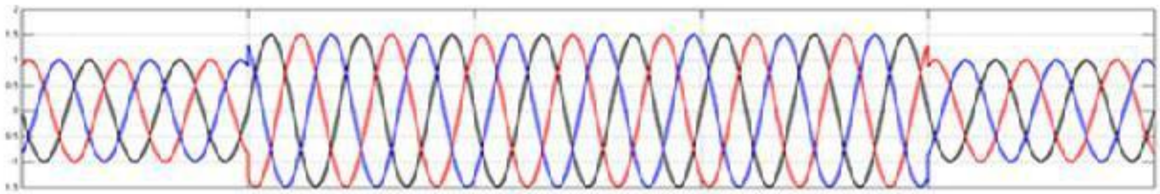

Fig.9 Voltage swell

iv)Voltage interruption:

The voltage is decreased to less than 0.1pu for a period not exceeding 1 min.

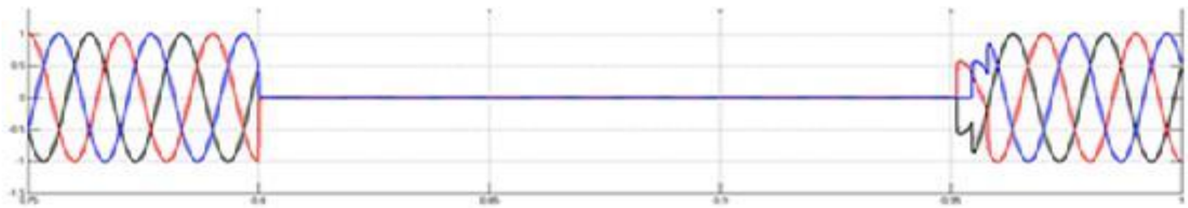

Fig.10 Voltage Interruption

v)Transient:

Transient is a sudden change in steady state condition of voltage, current or both.

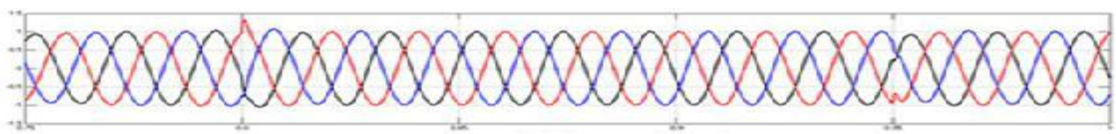

Fig.11 Voltage transient

EFFECTS OF VOLTAGE SAGS:

The problem of sag voltage is the most serious problem among the problems of power quality, where it leads to the flow of high current and thus damage sensitive devices such as: Computers, Programmable Logic Controller (PLC), Controller Power Supplies, Adjustable Speed Drives (ASD), Motor Starter Contactors. The voltage sag problems in industrial equipment include [9]

- Relays opening without overloading, because of the sag affecting the relay's coil voltage.
- Sensor voltage gives incorrect reports, such as water pressure sensors or air flow sensors.
- Circuit breaker or fuses operating, due to the large increase in current immediately after the sag.

CAUSES OF VOLTAGE SAG:

i)Voltage sag due to faults:

Voltage sags are mostly because of the power system faults. The severity of sag depends on the type of fault and the distance from the source and the fault, A three-phase fault near a distribution substation leads to all the customers connected to these substation will face deep sag[8] . The main reasons for power system fault are: weather (snow, wind, lightning) and interference from smaller animals and birds.

ii) Reclosure of circuit breaker: Operation of a circuit breaker or reclosure causes a temporary fault of a specific line. In case of weak grid, voltage sag in the neighboring lines will be occurred because of this temporary fault. The extent of the voltage sag is determined by distance from fault and supply voltage.

iii) Energizing the transformer: The medium voltage line contains many transformers. When operating this line, these transformers energize at the same time, which leads to a very high current flow. This causes the voltage drop for a short period. This drop is the voltage sag and its effect is obvious to consumers

iv) Starting of Induction Motor: Induction motors take a very high current in starting up about greater than five to six times the nominal value taken by the motor. This high current remains until the induction motor starts running with the nominal speed. The voltage drop depends on specifications of power system and the induction motor.

Voltage distortion limits IEEE

The voltage harmonic distortion limits apply to the quality of the power. For instance, for systems of less than 69kV, IEEE 519 requires limits of 3 percent harmonic distortion for an individual frequency component and 5 percent for total harmonic distortion.

Table 1: Voltage distortion limits for harmonics

Bus voltage	Individual V_h(%)	THDV(%)
V< 69 kV	3.0	5.0
69≤V<161 kV	1.5	2.5
V≥ 161 kV	1.0	1.5

POWER QUALITY IMPROVEMENT TECHNIQUES AND SOLUTIONS:

Power quality problems can be defined as the difference between the quality of power supplied and the quality of power required for reliable operation of the load equipment. Several types of power enhancement devices have been developed over the years to protect equipment from power disturbances. Some of the effective and economic measures can be identified as following:

i) Power conditioning devices,

ii) Custom power devices.

i) **POWER CONDITIONING DEVICES**:

1-**LIGHTNING AND SURGE ARRESTORS** :

Arrestors are using to protect The transformers from lightning and voltage surges but are certainly not sufficient for limiting voltage disturbances to protect sensitive electronic circuits from voltage surges.

2-**TRANSIENT VOLTAGE SURGE CAPACITORS (TVSC**):

These units clamp spikes to a level that it is safe for the sensitive loads. Employing an entire facility protection strategy will safeguard the electrical system against most transients.

3-**FILTERS: PROVIDE PROTECTION AGAINST HIGH FREQUENCY LOW VOLTAGE NOISES**.

Filters are designed to pass the fundamental frequency and reject the higher frequency noise such as electromagnetic interference (EMI) and ratio frequency interference (RFI). Harmonics filters prevent the harmonics content of non linear loads from back to the power source.

4-**ISOLATION TRANSFORMER**:

Provides a degree of filtering and isolation.Isolation transformers reduce electrical noise by separation of the primary and secondary through magnetic isolation. Isolation transformer reduce noises and harmonics but it does not compensate for power outages and voltage fluctuations.

5-**VOLTAGE REGULATORS**:

Voltage regulators maintain output voltage at nominal voltage under severe input voltage variations. There are three basic types of regulators:

i)**Tap changing Transformer**:Designed to adjust for varying voltages by automatically transferring taps on a power transformer. The main advantage of tap changers is high efficiency , wide input range, high over load current capability and good noise isolation compared to other voltage regulation technology. Disadvantages are noise

ii)**Buck boost**: Utilizes similar technology to the changers except the transformer being not isolated. One of the advantages is that it can withstand high in-rush currents. Disadvantages are noise created when changing taps, poor noise isolation and no waveform correction

iii) **Constant Voltage Transformer (CVT**): It is also known as Ferro resonant transformer. The CVT is a static regulator that maintains a nearly constant output voltage during large voltage variations in the input voltage. Advantages are superior noise isolation, very precise output voltage and current limiting for overload protection. The lack of moving parts means that the transformer requires little maintenance. Disadvantages are large size, audible noise and low efficiency.

6-**UNINTERRUPTIBLE POWER SUPPLY (UPS)**

UPS systems provide protection in the case of a complete power interruption. There are three major UPS topologies each providing different levels of protection : off-line UPS, Line interactive UPS and on-line UPS. Topology may be considered according to the load requirement based on efficiency, cost and transfer time. Moreover, UPS also requires a high level of maintenance because of, leakage of batteries and also needs replacement for every five years.

ii) **Custom power device**:

Customers are demanding electrical power with high quality from the electric utilities. Custom power devices are capable to solve power quality problems. The concept of custom power is based on the use of power electronic controllers in the distribution system for the purpose of providing reliable and high quality power that is needed by sensitive equipments to power quality variations.

TYPES OF CUSTOM POWER DEVICES

1-network reconfiguring type(switchgear): which used for power quality enhancement and these include: Static current Breaker(SCB), Staticurrent limiter (SCL) and Static Transfer Switch (STS).

i) Static Current Limiter (SCL):

SCL limits a fault current by quickly inserting a series inductance within the fault path. It consists of a pair of anti-parallel gate close up thyristors switch with snubbers (RC circuit) and a current limiting inductor. The currents limiter is connected serial with a feeder such it can restrict the present within the case of a fault downstream. within the healthy state, the other poled switch remains closed. These switches are opened, when a fault is detected, such the fault current now flows through the present limiting inductor [8]

ii) Static breaker (SCB):

SCB breaks a faulted circuit much faster than a mechanical breaker . An SCB has almost an equivalent topology as that of an SCL except that the limiting inductor is connected serial with an opposite poled thyristor pair. The Gate close up thyristor (GTO) are the traditional current carrying elements. The thyristor pair is switched on simultaneously because the bidirectional switch GTO is transitioned once a fault is detected. this may force the fault current to flow through the limiting inductor. The Thyristor pair is blocked after a couple of cycles if the fault still persists. the present through the thyristor pair will case to flow at subsequent available zero crossing of the current[8].

iii) Solid-State Switch supported The Thyristor Device (STS):

The properties of a thyristor (ON- state and OFF-state) are wont to perform an intelligent switch which may choose between two power sources and supply the simplest available power to the electrical load [9]. In most cases the STS is capable to limit the duration of voltage sags and interruptions to but 0.5 cycle by transferring the hundreds from the affected feeder to a backup feeder. STS response is extremely high speed [14] but when both the feeders are suffering from voltage disturbances STS become not suitable.

2 Compensating type system controller:

This is used for voltage regulation, Power factor correction, load balancing and active filtering. Compensating type are include: Distributed Static Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner.

i) **Dynamic Voltage Restorer to control power:**

DVR may be a compensating custom power type device. Voltage Source Inverter (VSI) of DVR generates a compensating voltage, which is then injected within the distribution system by means of series injection transformer. Passive filter connected between the VSI and therefore the injection transformer, eliminates the upper order harmonic components from the inverter output voltage. Energy memory device connected to the VSI provides the required active power for the compensation[14]. Dynamic Voltage Restorer compensation ability depends on the range of sags and size of the energy storage

ii) DSTATCOM:

Shunt devices are effective to compensate small voltage variation, which may be controlled by reactive power injection. the power to regulate the elemental voltage at a particular point depends on the impedance to the availability and therefore the power factor of the load. The compensation of a voltage dip by current injection is extremely difficult to realize, because the availability impedance is typically low and therefore the injected current has got to be very high to extend the load voltage

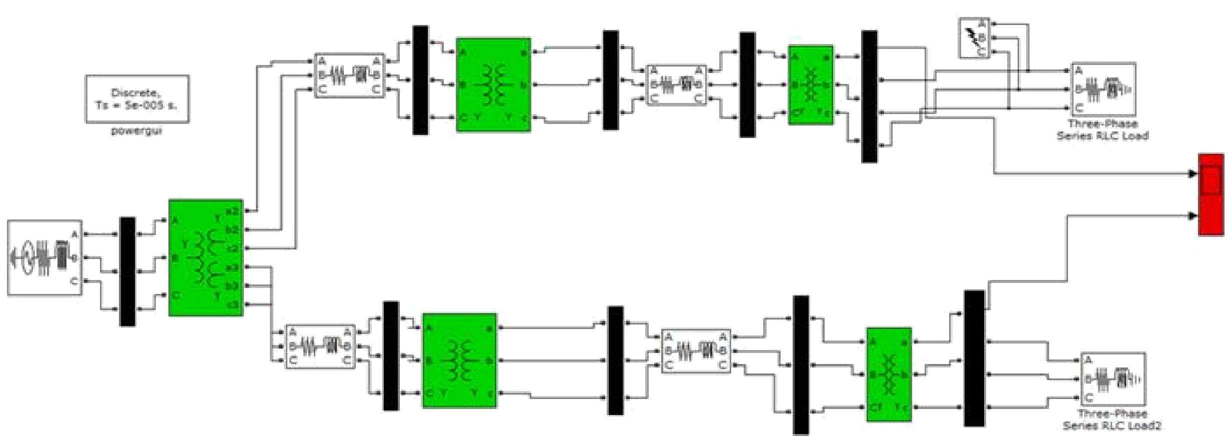

Fig.12 Simulink model of test system without custom power device

8-Simulation and Results:

1-Without custom power devices

Fig.12 shows the simulink model of the test system in which the two parallel feeders are cleared

i)Three phase to ground fault

In this test a three phase to ground fault is introduced in the first feeder. Here the fault resistance is (0.001 ohms) and the ground resistance is (0.001 ohms). The total fault duration is 0.15sec from 0.8s to 0.95s as shown in fig.13. Symmetrical sag is occurred automatically at adjacent feeder as seen in fig.14

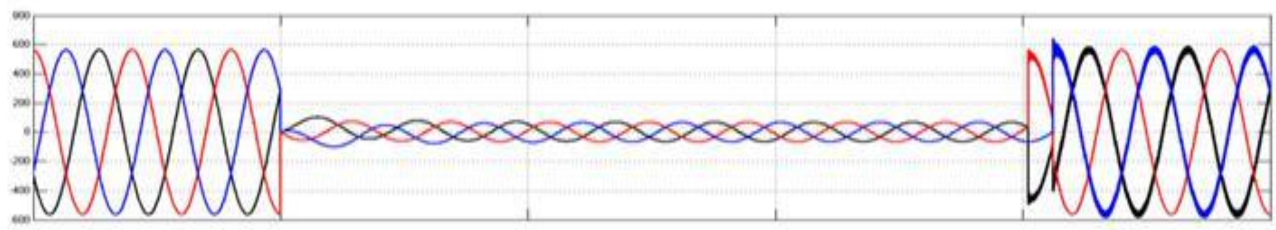

Fig.13 Load voltage at the feeder where the three phase to ground fault occurred

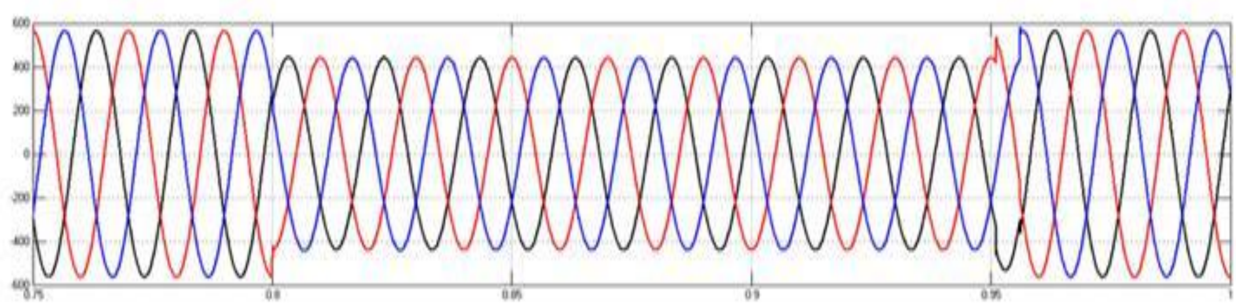

Fig.14 Load voltage at adjacent feeder

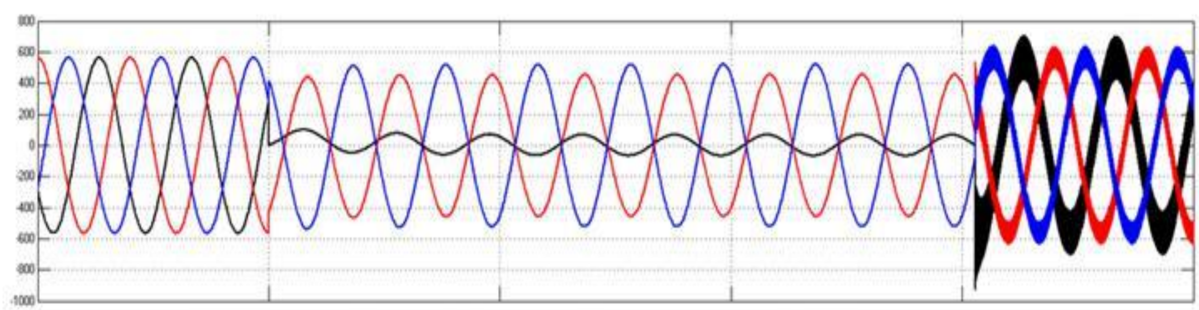

Fig.15 Load voltage at the feeder where single line to ground fault occurred

iii) Double line to ground fault: As shown in fig.15 double line to ground fault is simulated ,the fault resistance is (0.001ohms) and the ground resistance is (0.001 ohms

The total fault duration is 0.15s from 0.8s to 0.95s as can seen in fig.15.

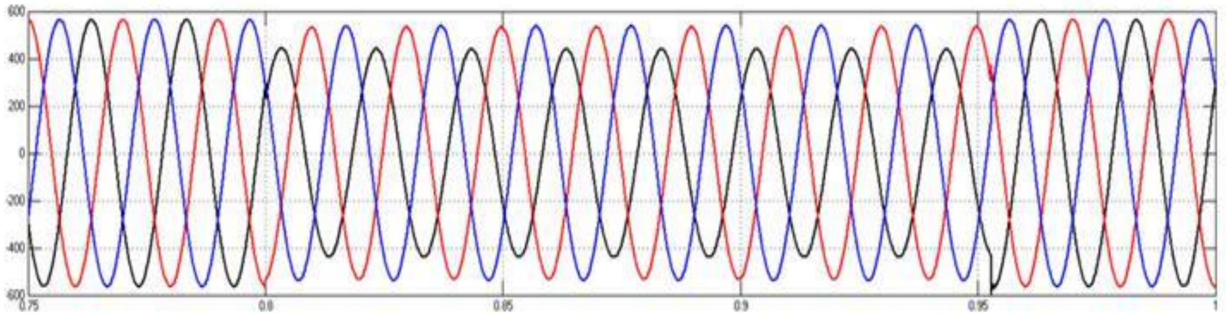

Fig.16 Load voltage at adjacent feeder

Asymmetrical sag is occurred automatically at adjacent feeder as shown in fig.1

2- With custom power device

Fig.17 shows the simulink model of the test system in which Dynamic Voltage Restorer(DVR) is connected at the second feeder

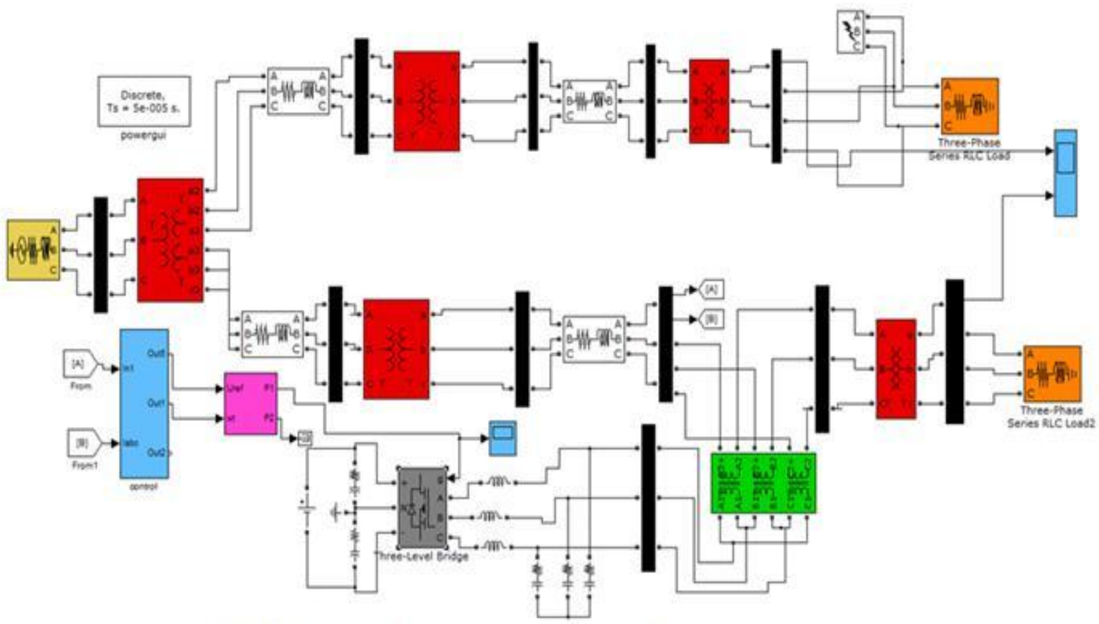

Fig.17 Simulink model of test system with custom power device

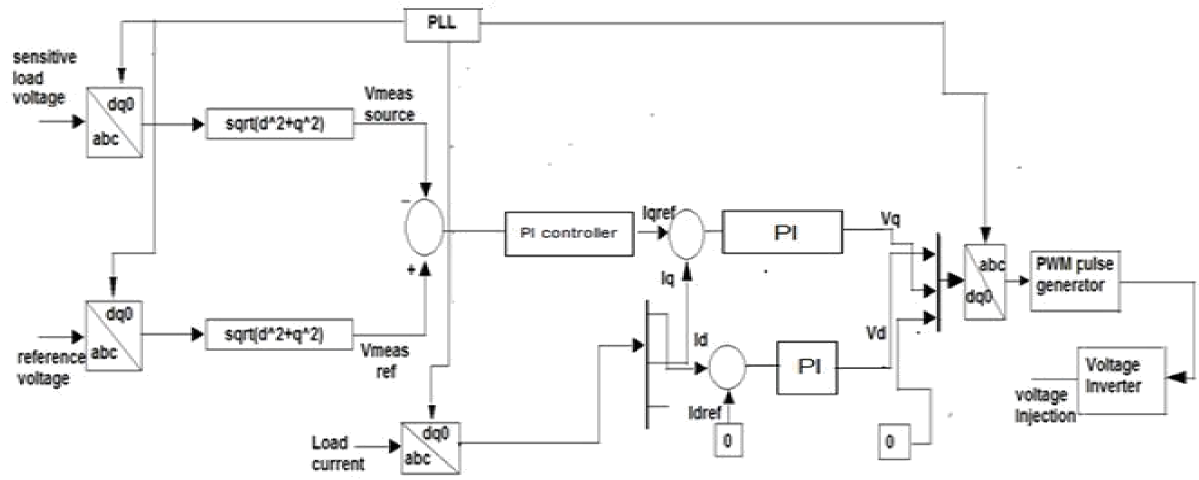

Fig.18 Block diagram of the DVR control unit

i) Three phase to ground fault: Custom power devices at the second feeder is restored the load voltage to the pre-sag value as shown in fig.19

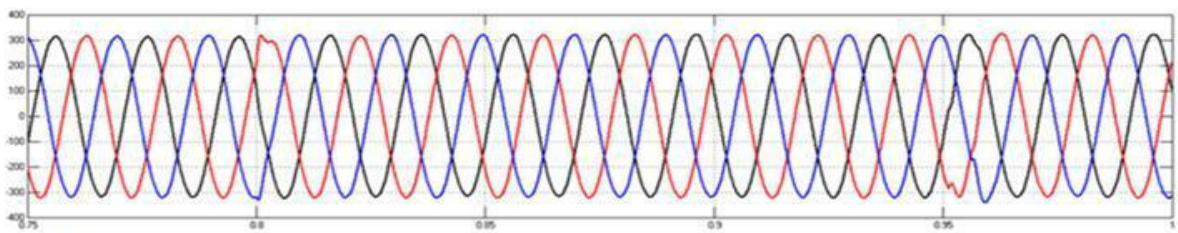

Fig.19 Load voltage during three line to ground fault for the adjacent feeder with custom power device

iii) Double line to ground fault: Fig.20 shown the load voltage at the second feeder. As can seen that the custom power device is capable to restore the load voltage to its nominal value

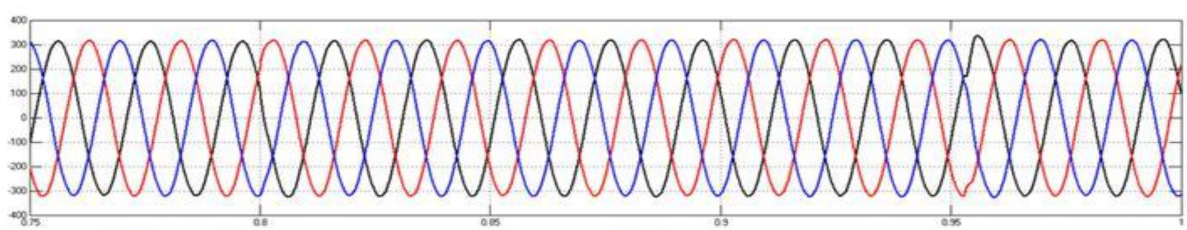

Fig.20 Load voltage during single line to ground fault for the adjacent feeder with custom power

CONCLUSION:

With the increasing use of sensitive loads, power quality problems such as voltage sags, swells, flickers and harmonics are introduced into the distribution system. Voltage sag and harmonics are most common power problems in the industrial sectors. Loss of synchronization of processing equipment and lock ups of computer is a severe problem for continuous manufacturing industries. Circuit breakers tripping and data loss is the main problem caused by poor power quality in the service and transport sectors. The FACTS devices are used to improve the power transfer capabilities and stability margins of the transmission line. The custom power devices are effective to restore the sensitive load voltage to the pre-fault value and make it smooth under different cases of faults and nonlinear load condition. Some of these custom power devices include: DSTATCOM, UPQC, and DVR etc. Among these Dynamic Voltage Restorer (DVR) which is series connected power electronic based device is one of the most efficient and effective custom power devices to protect the sensitive equipments against voltage sags and harmonics due to its lower cost, smaller size and dynamic response. The simulation results showed that the load voltage was compensated fully within the permissible THD limit with the help of the Dynamic Voltage Restorer which is one of the custom power devices types.

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