International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

Monitoring of Power Quality Issues, Assessment & Mitigation using Software Platform for College Campus

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Abstract— **As technologies are advancing amount of non-linear loads are increasing, which are leading to various issues like sensitive equipment malfunctioning, interruptions, etc. Due to which power quality has become a big concern. To improve the power quality and for solving the issues, study and analysis of system is necessary. This paper includes monitoring of power quality issues in college campus with the help of HIOKI PQ Analyzer PW3198. Study of various power quality events such as voltage sags, swell, interruptions and harmonics is carried out. To reduce these disturbances, mitigation techniques have been introduced, such as passive harmonic filters to reduce harmonic distortion. So overall conclusion is that Power quality maintenance is an important aspect in the economic operation of a system and various power quality problems may lead to another undesirable problems so proper mitigation devices can be used to maintain the level of power quality.**

***Keywords**—Power quality, power quality event, mitigation techniques, MATLAB.*

1.INTRODUCTION

The electrical power system includes three main working area such as generation, transmission and distribution which delivers rated voltage, current simultaneously at rated frequency without any disturbance to consumers. Power quality refers as powering and grounding the sensitive electronic equipment in such a way which would be suitable for the equipment. It is a set of electrical boundaries allowing a piece of equipment such as it can function in its intended task without loss of performance or life expectance. Power quality refers to the characteristics of electrical power that affect the performance and reliability of electrical equipment. The quality of power can be impacted by various events that cause disturbances or deviations in the power system. These events can be classified into two broad categories voltage disturbances and waveform distortions. Voltage disturbances refer to events that cause variations in the amplitude, duration, or frequency of the voltage. Waveform distortions refer to events that cause changes in the shape of the voltage or current waveform.

A good power quality is essential for the safe and efficient operation of electrical systems and equipment, as well as for minimizing energy losses and reducing costs. Poor power quality can result in a range of problems, such as equipment damage, malfunction, reduced lifespan, and safety hazards.

The sources of power quality problems can be internal or external to the power system, and can include voltage sags, swells, harmonics, transients, and other disturbances. Power quality monitoring, analysis, and mitigation techniques are used to identify and resolve these problems, and to ensure that the power supply meets the required standards and specifications. This paper includes a power quality audit which is conducted at college substation at point of common coupling. The experimental data is collected with the help of analyzer. The power quality parameters are monitored such as harmonic distortion, voltage and current imbalance and power factor. After analysis harmonic distortions are seen so mitigation technique is implemented with help of software platform so that it could increase the reliability and stability of the power system. Power quality problem is very huge and it results in financial cost so for increasing efficiency of power system regular assessment is required.

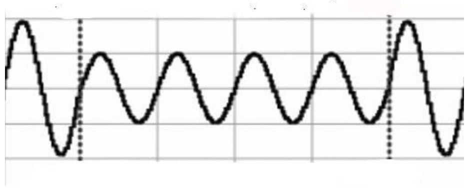
The rest of the paper includes: In section 2 power quality disturbance their causes and effects are been explained briefly; section 3 includes methodology used for monitoring and analysis of the results; in section 4 possible mitigation technique is proposed for end users; section 5 includes simulation and results and section 6 is devoted to the conclusion.

2. POWER QUALITY EVENTS

The equipment and electronic device can face problem with bad quality of power which can lead to symptoms such as maloperations of drives, poor performance, flickers in lamps, tripping of contractors and relays, system restarting or loss of data, etc. So, the power quality events include voltage sag, voltage swell, flickers, interruptions, voltage unbalance, transients, frequency deviation, harmonics, under voltage and over voltage, electrical noise, blackouts and brownouts.

A. Voltage Sag (Dip)

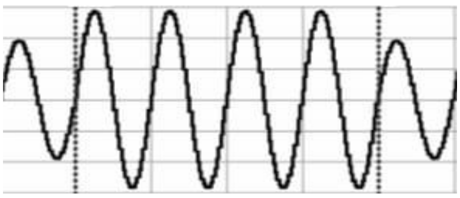
Voltage sag, also known as voltage dip or voltage drop, is a temporary reduction in voltage level below the normal voltage level for a short period of time. This can cause various issues in electrical systems and devices or it is sudden decrease in rms voltage or current at point of common coupling (PCC) between 0.1 to 0.9 p.u. for duration of 0.5 cycle to 1 minute.



Causes of voltage sag include: Faults in the power system, such as short circuits or ground faults, Starting large electrical loads, such as motors or transformers. The effects of voltage sag can include: Damage to electrical equipment, including motors, drives, and control systems and Reduced productivity or shutdown of industrial processes and machinery. Solution for it is: improve immunity of equipment by using UPS.

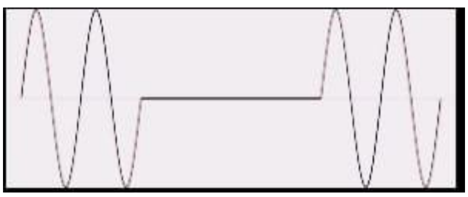
B. Voltage Swell

Voltage swell is a type of power quality disturbance that refers to a temporary increase in voltage levels above the nominal voltage level for a period of time. This increase in voltage can last from a few milliseconds to several seconds and can be caused by a number of factors or sudden increase in rms voltage or current between 1.1 p.u to 1.8 p.u. for duration from 0.5 cycles to 1 minute. Causes of Voltage Swell: Faulty transformers, Lightning, Faulty equipment, Load switching, Network faults. Effects of Voltage Swell: Reduced lifespan of equipment, Reduced efficiency, Malfunctioning of electronic, Overheating, Fire risk.



C. Voltage Interruption

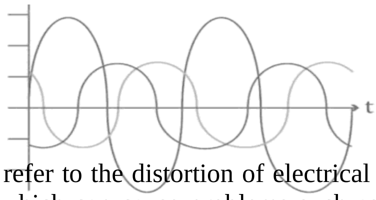
These occur when supply voltage or load current decrease to less than 0.1 p.u. for time period less than 1 minute duration. A voltage interruption, also known as a power outage or blackout, occurs when there is a sudden loss of electrical power to an area. This can happen for a variety of reasons, such as a fault in the electrical grid, severe weather conditions, or equipment failure. Interruption is classified in three categories: Instantaneous Interruption, Momentary Interruption and Temporary Interruption. Source are HV, MV & LV lines or installation and operation of automated system. At time of operation of protective devices and isolating faulty section. Effects are slowing down and stopping of Induction Motor, Crashing of computer system, Tripping of contractor Failure of commuted inverter: UPS and stabilizers for computer, control and drive system.



D. Voltage Unbalanced

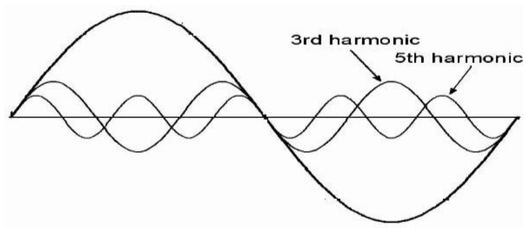
Voltage unbalance occurs when the three phases of a three-phase power system are not at the same voltage level. There are several possible causes of voltage unbalance, including: Imbalanced loads, faults in the system, voltage drop in distribution system. The effects of voltage unbalance can be significant, including: Increased motor heating, decreased motor performance, equipment damage, unreliable operation, power quality issues.

E. Harmonics



Harmonics refer to the distortion of electrical signals in a power system, which can cause problems such as equipment damage, power quality issues, and increased energy consumption. The cause of harmonics is usually non-linear loads, such as electronic devices, that draw non-sinusoidal currents from the power supply. These non-sinusoidal currents generate additional frequencies, known as harmonics, which can interfere with the power system's normal operation. The effects of harmonics can be quite significant, including increased heat generation in equipment, reduced equipment lifespan, and higher energy consumption. Harmonics can also cause voltage and current distortions, which can result in voltage dips, flicker, and even power outages. Furthermore, harmonics can lead to interference with other electronic devices and communication systems, leading to signal degradation and other problems.

To mitigate the effects of harmonics, power system designers and operators can take several measures, including installing harmonic filters, selecting equipment that is less susceptible to harmonic distortion, and implementing power factor correction. Additionally, there are various standards and guidelines, such as IEEE 519, that specify acceptable levels of



harmonics in power systems to ensure reliable and efficient operation.

3. Monitoring and Analysis of Events

The case study considered in this paper is distribution network feeding the engineering building of K.K.Wagh Institute of Engineering Education and Research college in Nashik. The building under investigation contains several lecture rooms, academic offices, seminar halls, experimental and computer laboratories, library and girl's hostel. The incoming supply is of 11kv which goes to metering room then to 500 kVA, 11/0.415kV transformer named as college substation. At secondary side of transformer there are total six feeders which includes engineering & girls' hostel (630 A), polytechnic & boys' hostel (400 A), pharmacy (250 A), workshop (250 A), fire safety (160 A) and APFC panel. For monitoring purpose, the HIOKI Power Quality Analyzer (PW3198) is connected to the engineering building and hostel feeder.

Parameters such as current, voltage, active and reactive power, power factor, unbalance factor and harmonic distortions were measured to determine the power quality of the installation. Monitoring was done for six hours on a working day. The analysis of the measured data can be used for the evaluation and possible implementation of mitigation techniques. The analyzed power quality issues presented in this paper are based on measurement.

A. Analysis of Voltage

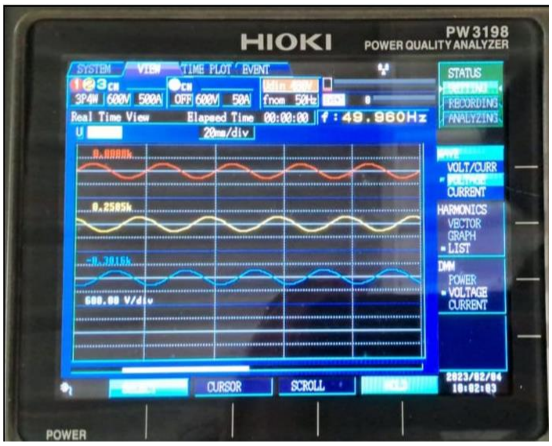


Fig. 3.1: Distortion in voltage waveform

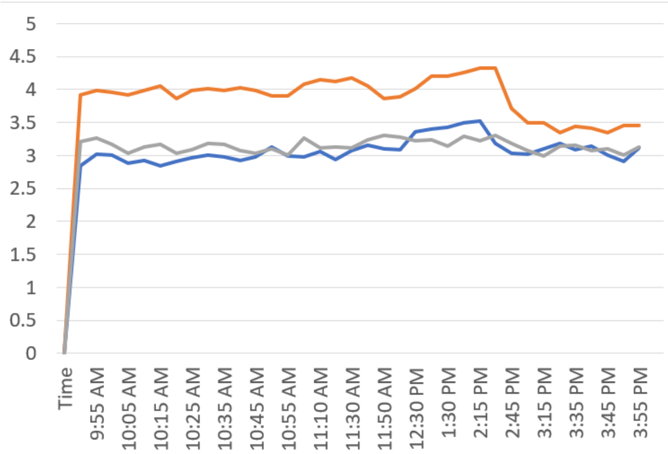


Fig. 3.2: Total harmonic distortion of voltage per phase

The voltage measured on all phases show some level of fluctuation according to load characteristics. The variation of voltage was within limit of 230V and variation of 6% was observed. The distortion in voltage waveform was minimal as illustrated in Fig.3.1. From Fig.3.2, the distortion in supply voltage waveform was also seen for the three phases. The average total harmonic distortion of the voltage recorded for the measurement period was 3.37% which is considered within the limit. So, the dominant harmonic order are 3rd, 5th and 7th harmonics.

A. Analysis of Current

The current measure at all the phases during the period shows the variation according to load characteristics of the Engineering building. The higher amount current harmonic distortion was observed as shown in Fig 3.3. In Fig 3.4 Ithd % vs time interval graph is shown. The distortion in current waveform was also seen for three phases. The average distortion for current recorded for the measurement period is 38.22% which is considered according to IEEE standard as high while third, fifth and seventh harmonic was dominant.

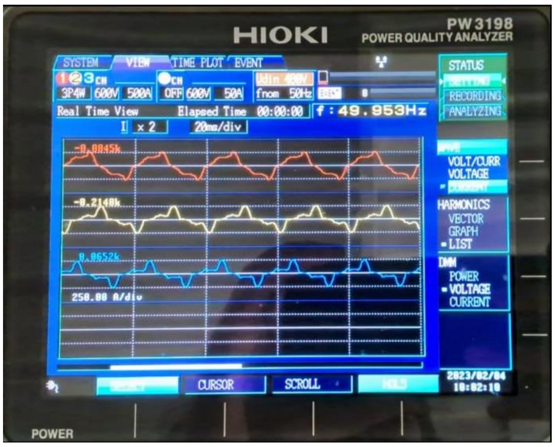


Fig. 3.3: Distortion in current waveform

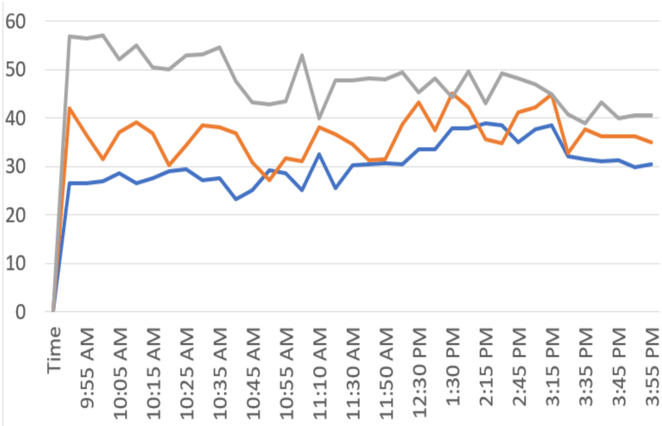


Fig. 3.4: Total harmonic distortion of current per phase

B. Analysis of Harmonics

The recorded order of harmonics is shown in Fig. 3.5 from which the dominant harmonics such as 3rd, 5th, 7th and higher order of harmonics are observed. Fig. 3.6 shows total harmonic distortion vs time interval graph from which the 3rd and 5th order of harmonics are more dominant.

Fig. 3.5: Harmonic Analysis

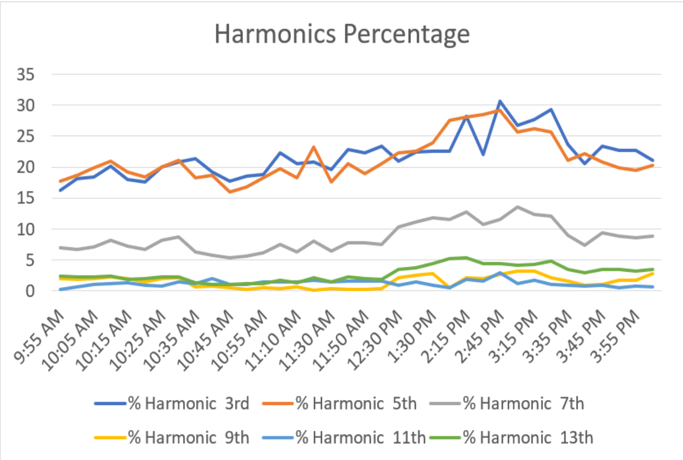


Fig. 3.6. Total harmonic distortion

4. Mitigation Technique

Power quality refers to the degree to which the electrical power supplied to a device or system is consistent with the desired parameters. Poor power quality can result in a variety of problems, including equipment malfunction, data loss, and increased energy consumption. Mitigation techniques are used to improve power quality and ensure that electrical power is delivered at the desired level of quality. Some common techniques used for power quality improvement are voltage regulation, power factor correction, harmonic filtering, surge suppression, grounding, uninterruptible power supply (UPS), distribution generation, etc.

Three phase four wire distribution system are mostly used in commercial, residential and industrial, therefore there is huge chance of harmonic distortion. Power Quality monitoring and assessment are important to check the maximum deviation. Mitigation technique for harmonics can be passive filter and active filter. Passive filter is known technique to mitigate or solve the issue. Active filter has function of passive filter but active filter is very costly. So, solution for harmonic distortion produce after monitoring and assessment is Passive filter. A passive filter is an electronic circuit that uses only passive components such as resistors, capacitors, and inductors to filter unwanted frequencies from a signal. Passive filters are used to remove unwanted noise or harmonics from a signal, to create a specific frequency response, or to separate different frequency components of a signal. Passive filters are called so because they do not require an external power source to function. The operation of passive filters is based on the principles of reactance and impedance of the passive components, which can be varied by changing the values of the components in the circuit.

There are several types of passive filters, including low-pass, high-pass, band-pass, and band-stop filters. A low-pass filter allows frequencies below a certain cutoff frequency to pass through while attenuating higher frequencies. A high-pass filter does the opposite, allowing frequencies above a certain cutoff frequency to pass through while attenuating lower frequencies. A band-pass filter allows a specific band of frequencies to pass through while attenuating frequencies outside of that band, while a band-stop filter (also known as a notch filter) does the opposite, attenuating a specific band of frequencies while allowing frequencies outside of that band to pass through. Passive filters are widely used in a variety of electronic devices, such as audio equipment, telecommunications systems, and power supplies. They are simple, low-cost, and reliable, making them a popular choice for many applications.

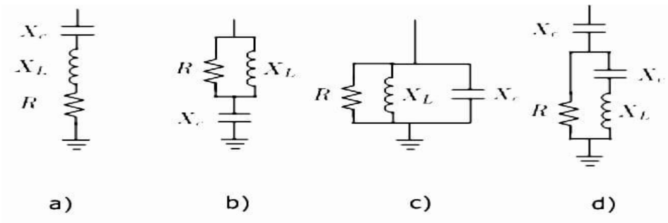


Fig. 4: Passive Filter

From above figure we can see different types of passive filter which include a) Single-tuned passive filter b) High-Pass passive filter c) Band-Pass passive filter d) C-type. Single-tuned filter is used to mitigate 3rd ,5th and 7th order harmonics, Double-tuned filter is used to mitigate 5th and 7th order harmonics and High-pass filter is used to mitigate 3rd and above order harmonics. So passive filter is the solution to reduce or mitigate harmonics which are produced after monitoring and analysis of power quality events.

5. Simulation and Results

In simulation a three-phase system feeding a rectifier as well as an unbalanced RC load is taken for analysis and is modelled along with Filter for Power Quality improvement by mitigation of various order of harmonics injected into the system by non-linear loads. In distribution system harmonics sources are not concentrated at single point and can be distributed all along the feeder. So, the location of filter for such loads is difficult. If location of filter is connected at secondary of distribution transformer, then passive filter is cheap and best choice for reduction in harmonic as a filter. The capacitors of harmonics filter were sized according to reactive power requirement of the system. Simulation models includes Diode bridge Rectifier load and Diode Bridge RC Load which are developed in MATLAB software, and the model of nonlinear loads are described given below to simulate the power quality disturbances.

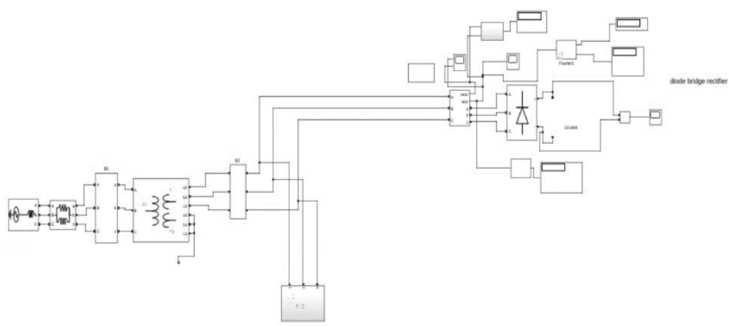


Fig. 5.1: Simulation of Diode bridge Rectifier

International Journal of Scientific Research in Engineering and Management (IJSREM)
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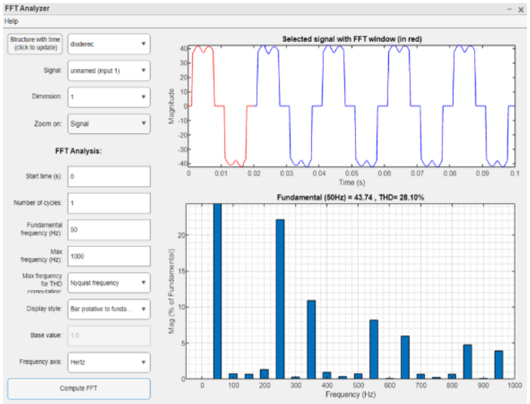
A. Simulation model of Diode bridge Rectifier load

The model consists of 11kv 50Hz three phase voltage source block in series with RL branch feeding through transmission line to the load. The FFT analysis is important to



calculate the percentage distortion caused in an ideal waveform due to disturbances. The FFT analysis results which are carried out on diode bridge rectifier is given as follows:

Fig. 5.2: FFT Analysis of Diode bridge Rectifier without filter

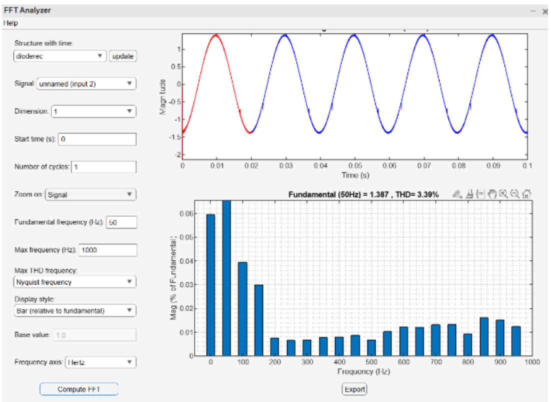


Fig. 5.3: FFT Analysis of Diode bridge Rectifier with Single Tuned filter

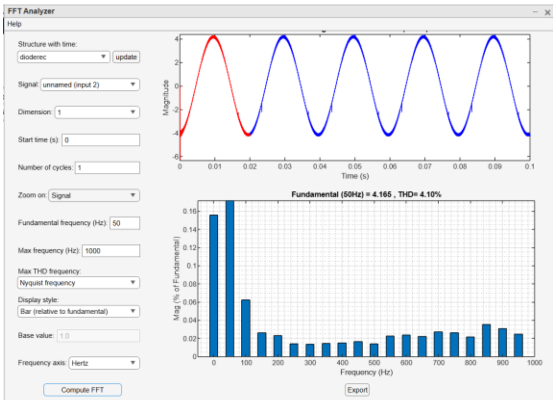


Fig. 5.4: FFT Analysis of Diode bridge Rectifier with Doubled Tuned filter

Fig.5.2 shows that before the implementation of passive filter, the THD is about 28.10% and after implementation THD is reduced to a great value which is desirable. The THD is reduced to 3.39% with Single tuned passive filter and to 4.10% with Doubled tuned passive filter. By implementing High pass filter the THD is reduced to 0.56% as shown in Fig. 5.3, 5.4 & 5.5 which is a better result in comparison with IEEE 519 standard recommendations by which THD of a waveform should not be greater than 5%.

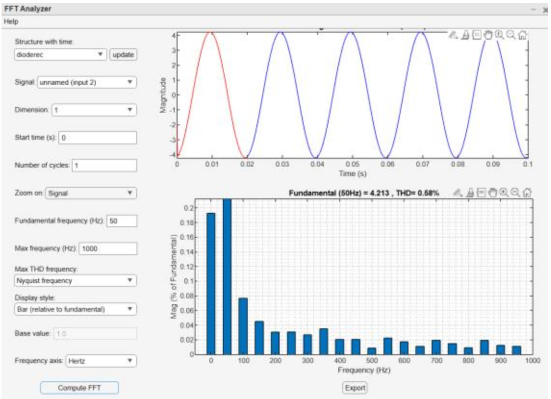


Fig. 5.5: FFT Analysis of Diode bridge Rectifier with High Pass filter

B. Simulation model of Diode Bridge RC Load

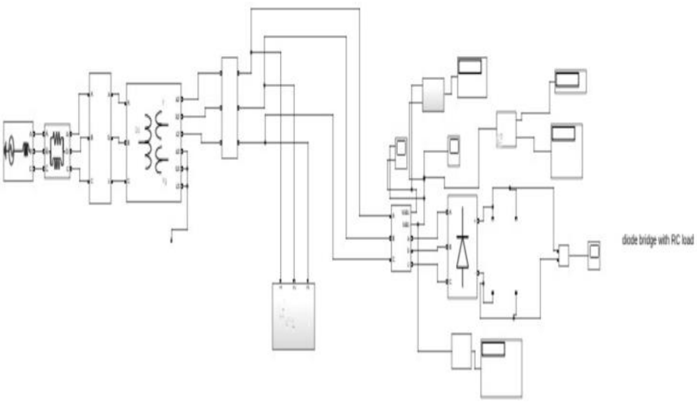


Fig. 5.6: Simulation of Diode bridge RC load

The model consists of 11kv 50Hz three phase voltage source block in series with RC branch feeding through transmission line to the load.

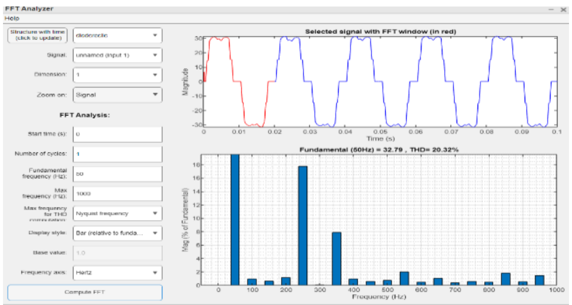


Fig. 5.7: FFT Analysis of Diode bridge RC load without filter

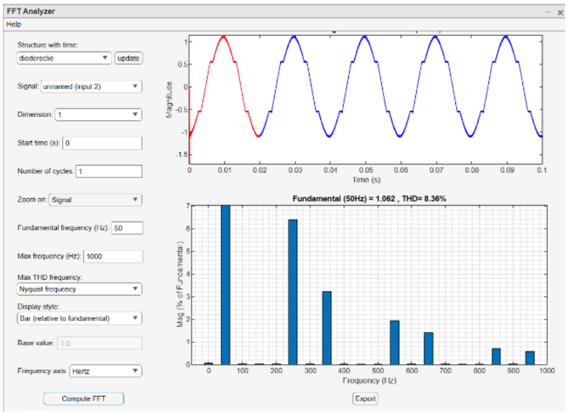


Fig. 5.8: FFT Analysis of Diode bridge RC load with Single Tuned filter

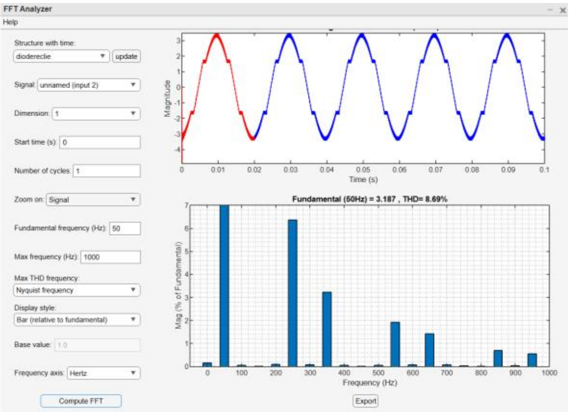


Fig. 5.9: FFT Analysis of Diode bridge RC load with Doubled Tuned filter

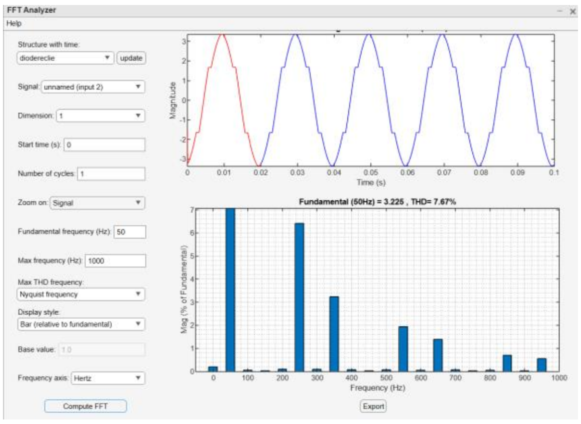


Fig. 5.10: FFT Analysis of Diode bridge RC load with High pass filter

Fig.5.7 shows that before the implementation of passive filter, the THD is about 20.32% for Diode bridge RC load and after implementation THD is reduced to a great value which is desirable. The THD is reduced to 8.36% with Single tuned passive filter and to 8.69% with Doubled tuned passive filter. By implementing High pass filter the THD is reduced to 7.67% as shown in Fig. 5.8, 5.9 & 5.10 which is a better result.

6. Conclusion

In these paper monitoring and analysis is done in which the results shows that 3rd, 5th and 7th harmonic is dominant. So, mitigation technique is been implemented for harmonic reduction and simulation model with FFT analysis results for power quality disturbance are developed in MATLAB software. Overall conclusion is that Total Harmonic Distortions reduced through simulation model for power quality improvement purpose.

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