Enhancement of Power Quality Applying Hysteresis Controller to Shunt Active Power Filter

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Abstract*—Power electronics technology has advanced in recent years and is now employed in many different applications. Moreover, this gadget contributed to the electrical system's power quality issue. One example of a non-linear load that generates harmonics of current on the utility side is an arc furnace. Other examples include variable frequency drive (VFD), personal computers, as well as fluorescent lights. Power quality is a significant problem on the consumer and distributed sides. the reactive power compensation and improvement capabilities of the active power filter. The harmonics problem that is caused by non-linear load is the topic of discussion in our project. For the purpose of removing harmonics from loads that are not linear, shunt active filtering techniques are used, whilst hysteresis power controllers are utilized in retrieval approaches for the purpose of controlling current. The notion of instantaneous reactivity (PQ) has been used throughout the whole of the process of developing our reference current. Through the use of the MATLAB Simulink toolbox, the simulation outcome of SAPF utilizing PQ concept is carried out. The project is concluded with a description of the SAPF system's efficiency in reducing harmonics and enhancing power quality.

***Keywords*—Hysteresis Current Controller, FACTS, SAPF.**

I. Introduction

The electricity distributor and the end user are getting more and more bothered about the quality of power that's being distributed to them and which is being used by the end users. Electricity with unacceptable standards and with bad quality is dangerous as well as waste of energy and also it is uneconomical for both utility and consumer end. Therefore, a proper measure is needed to focus on the quality of power which is supplied to the loads. Power outages and other power quality interference are costing county's millions of dollars. As the demand for the power supply increasing around the globe and hence, the thirst for new energy sources is unsatisfied but in real time we didn't able to realize that we are wasting a part of electrical energy and there is need to avoid this wastage of energy and supply power with gratifying quality to get maximum benefits.[1] Basically power quality means the quality of electrical loads that is being supplied. A good power quality is that in which there are no losses of power either in generating side or transmission side or load side. [2] Nowadays large-scale applications are being used due to the large demand in economy. The power system is becoming more complex day by day. For those reasons large equipment are used in which induction motors plays a major role which generates harmonics. There are numerous definitions of power quality that can be found in books and on the internet. However, according to the standards of the Institute of Electrical and Electronics Engineers (IEEE), power quality is defined as "the concept of powering and being grounded delicate electronic devices in a manner suitable for the equipment." In other words, power quality (PQ) is established as a set of electrical limits that enables an equipment to function without experiencing a significant loss of significant loss of performance or life cycle.

II. HARMONICS

The numerous integers of the basic frequency are what are supposed to be considered in harmonics. When there is a linear load, the current that is pulled is perfect, and it also produces a sinusoidal wave that is pure. This particular kind of load does not exhibit any deviance. The current voltage that is drawn is not exactly constant when the load is nonlinear. Recent deviations are seen in the data. Rather of providing a perfect sinusoidal wave form, it produces a distorted version of the pure sinusoidal wave form that includes harmonics. On the other hand, non-linear loads, variable speed motors as well as drives, switch method power supplies, photocopiers, computers, laser printing devices, fax machines, battery chargers, along with uninterruptible power supply (UPS) units are some examples of non-linear loads. Harmonics, which are distortions of the typical waveforms of electrical current, are typically produced by non-linear loads. An electrical signal's harmonics are components whose frequency waveforms are integral multiple of the fundamental frequency waveform [4]. There are several problems caused by harmonics generation in electrical power system, The excessive heating of transformers (k-factor) along with rotating equipment are some examples of the problems that can be caused by harmonics. Other problems include neutral overloading as well as not appropriate neutral grounding voltages, crashed capacitor banks, breaker trips, along with the unreliable performance of electronic devices as well as generators (ineffective distribution of power).Harmonics distort the entire signal and lower the system's overall power quality. One of the main issues for electricity and utility customers is harmonic distortion as a result of the extensive integration of non-linear loads into the power grid. The purpose of harmonic source detection is to mitigate harmonics and share harmonic responsibility [5].

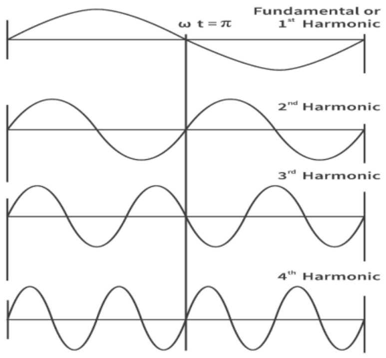

Fig.1 Harmonic

III. SHUNT ACTIVE POWER FILTER

Ripple filter, Voltage source inverter, and pulse width modulation for 3 phase system make up the shunt active filter. Reference signals can be produced to help the system get rid of the harmonics. One form of power electronic gadget that is used to reduce the amount of harmonic distortion that occurs in power systems is known as a shunt-activated power filter (SAPF). Here are some short notes on SAPFs based on research:

- Reactive power compensation is another use for SAPFs that may be employed, in addition to harmonic compensation. By injecting a current with a leading or lagging phase angle, SAPFs can help to balance the reactive power in the system, improving power factor and reducing energy costs.

- SAPFs can be implemented using different control strategies, including in addition to predictive current control, hysteresis current control, and pulse width modulation (PWM) are also available. The choice of control strategy depends on the specific application and the desired level of performance.

- SAPFs can be implemented using different topologies, including two-level, three-level, and multilevel converters. Multilevel converters are particularly useful for high-power applications, as they can reduce switching losses and improve efficiency.

- SAPFs can be combined with other power quality improvement techniques, such as active voltage regulation and series active filters, to provide a comprehensive solution for power quality issues.

- SAPFs are increasingly being used in systems that generate energy from renewable sources, such as solar and wind power plants, to reduce the impact of power electronics on the grid and improve power quality for end-users.

Overall, SAPFs are a versatile and effective tool for improving power quality in a diverse array of applications, as well as continuing studies and advancements in this area are focused on improving efficiency, reducing costs, and expanding the capabilities of SAPFs for future energy systems. Active filters have been shown to be the most effective remedy for power quality problems over the past three decades because of their small size, light weight, ability to eliminate harmonics, and other factors [7].

IV. PROBLEM IDENTIFICATION

Harmonics causes many problems in electrical power system operation. Majorly Harmonics are generated when non-linear loads come into use. As we see in present time the whole world is surrounded by the usage of nonlinear load for example laptops, computers, A.C. etc. All our daily life electrical equipment's majority are nonlinear load, and these non-linear loads generates Harmonics which distorts the current waveform and causes multiple problems in power quality of electrical systems.

A three-phase source, a three-phase series RL branch, and a three-phase V-I measurement are all components of the three-phase, nonlinear model that was constructed in MATLAB/SIMULINK. Additionally, the distribution system includes a nonlinear load. Further nonlinear load is a set of two different nonlinear loads are rectifier and shunt resistive unbalanced load which is connected in parallel which is shown in figure The purpose of connecting two different nonlinear loads in the system is to introduce hazardous harmonic in the system which will be further mitigate using SAPF.

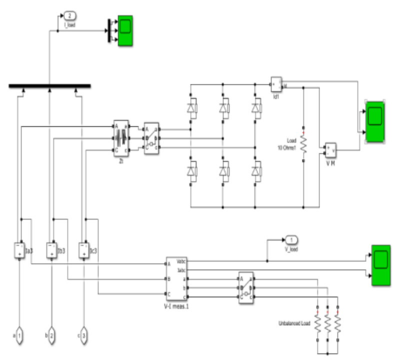

Fig.2 Nonlinear loads

It is calculated that there is hazardous harmonic introduced in the system which is observed as THD = 30.26% which can cause severe damage to the system and figure, shows the power quality disturbances waveform of load voltage, load current and source current in the system.

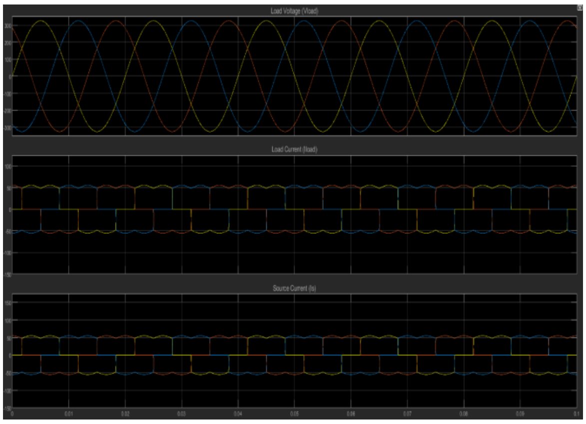

Fig.3 Waveform of source and load current without SAPF

V. PROPOSED METHODOLOGY

The level of consistency and dependability of the electrical power supply that is provided to electrical equipment and devices is referred to as power quality. Low-quality power can cause equipment to malfunction, experience downtime, and cause other issues.

It is crucial to have a steady and continuous power supply that is free from these disruptions in order to guarantee adequate power quality. This can be done by utilizing several power quality improvement approaches, including surge protectors, voltage regulators, and power conditioning devices. Furthermore, good grounding and wiring techniques might aid in enhancing power quality.

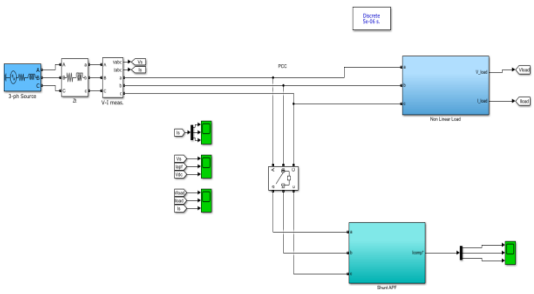

Fig.4 Simulink model with SAPF

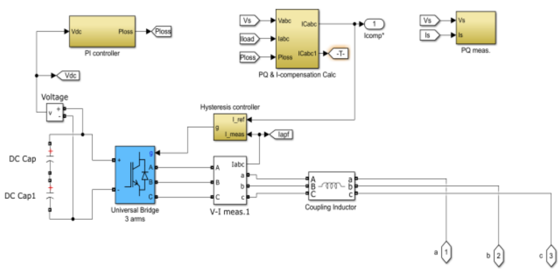

Fig.5 Simulink model of inside SAPF

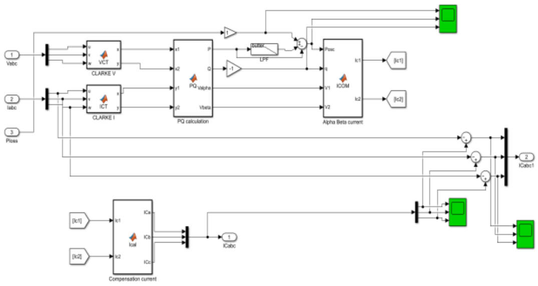

Fig.6 Simulation for I compensation

Conversion of three phase source voltage ABC and three phase load current ABC into two orthogonal components, called the alpha and beta components, which can be easily analyzed and controlled using the Clark's transform.

Using the formula shown below:

$$x = \sqrt{\left(\frac{2}{3}\right) * (u - (0.5 * v) - (0.5 * w)}$$

$$y = \sqrt{(2 \ * (0 + (0.5 * v) - (0.5 * w))}$$

Now using the above obtained value of Valpha and Vbeta using the Clark's transform for P and Q calculation:

In power systems, PQ calculation refers to the determination of active power (P) and reactive power (Q) flowing in a load or generator. The Clarke Transform, which converts the three-phase quantities to two-phase quantities, can be used to calculate P and Q using the alpha and beta components of the voltage h (V alpha and V beta).

Using the formula given below, we get the value of active power P and reactive power Q:

$$P = (x1 * y1) + (x2 * y2)$$

$$Q = (x2 * y2) - (x1 * y2)$$

Where x1 and x2 are – Valpha and Vbeta and y1 and y2 are Ialpha and Ibeta respectively

Using the values obtained above now use them to calculate Ic1 and Ic2:

Here P is converted to Posc using the LC low pass filter and Q is given a gain, on the other hand V1 and V2 are directly forwarded without any change. It is essential to calculate Ic1 and Ic2 so that we can use it to obtain the compensation current by inserting its values in the next block.

$$Ic1 \ = \ (-1/\ (V12 \ + \ V22)) * ((Posc * V1) \ + \ (q * V2)$$

$$Ic2 \ = \ (-1/\ (V12 \ + \ V22)) * ((Posc * V2) - (q * V1))$$

Conversion of the obtain Ic1 and Ic2 into three phase compensation current Ica, Ice and ICC using the formula given below:

Because most power systems, particularly AC power systems, are three-phase, alpha-beta current must be converted to three-phase current. Three separate alternating current waveforms are 120 degrees out of phase

$$ICa \ = \ sqrt\ (2/3) \ * (Ic1)$$

$$ICb \ = \ sqrt\ (2/3) \ * ((-0.5 * Ic1) \ + ((sqrt(3)/2) * Ic2))$$

$ICc = sqrt(2/3) * ((-0.5 * Ic1) - ((sqrt(3)/2) * Ic2))$

$ICabc$ that we obtain from here is the compensation current which will be used by hysteresis for the harmonic correction.

Here in the hysteresis controller, to generate the gate pulses using hysteresis current control, we first need to define the hysteresis band around the reference current. The hysteresis band is defined by two thresholds, the upper threshold (I upper) and the lower threshold (I lower), which are set based on the desired control requirements and the characteristics of the power converter.

Once the hysteresis band is defined, the reference current (I_{ref}) is calculated based on the measured output current ($I_{measured}$) and the compensation current ($I_{compensation}$), if any. The equation for calculating the reference current with compensation is:

$I_{ref} = I_{measured} + I_{compensation}$

The reference current is then compared with the upper and lower thresholds to determine the output state of the control system. If the reference current exceeds the upper threshold, the control system generates a gate pulse to reduce the duty cycle of the converter. If the reference current falls below the lower threshold, the control system generates a gate pulse to increase the duty cycle of the converter. If the reference current is within the hysteresis band, no gate pulse is generated and the converter continues to operate at its current duty cycle.

Then the output is given to the universal bridge, which supplies the value to the system

VI. RESULT

The suggested model of a Shunt active power filter (SAPF) is emulated for a three-phase power distribution network using the MATLAB platform in conjunction with Simulink. The results of this simulation are shown in figure 5.1.1. The term "nonlinear load" refers to a load that is linked in parallel with two other nonlinear loads, namely a rectifier and a resistive unbalanced load, both of which possess a nonlinear characteristic. There is a source of 400V Voltage and 50Hz that is delivered into the system. It has been determined that the Total Harmonic Distortion (THD) is 30.26 percent when there is no filter present on the supply side. In situations when the Shunt APF does not provide a compensating current, it has been found that the amplitude, waveform pattern, and total harmonic distortion (THD) of the supply side current (Is) and the load side current (I load) are identical.

An analysis known as FFT, which stands for fast Fourier transform, is carried out in order to identify the components of the supply current's harmonic. The 5th and 7th harmonics are determined to be the most prominent harmonic components. Hence these components of harmonic are mitigated in this study.

Therefore, to mitigate the harmonic components, we connected a Shunt active power filter through PCC, SAPF uses the combination of PI and PQ controller to generate a reference current which is compared with the measured value of current to generate a compensation current using the Hysteresis Controller.

Without compensation, the current that is supplied is non-sinusoidal, which means that it is warped. This is something

that can be seen. Following the use of SAPF compensation, the source current becomes almost sinusoidal as a result of

the deformed wave. Shown in figure hence the percentage value of THD is reduced to 5.70%.

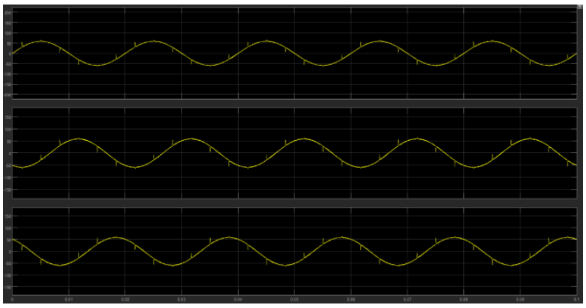

Fig.7 Waveform of source current after using SAPF

VII. CONCLUSION

In today's world, electric vehicles are a prime example of one of the efficient technologies. Additionally, employing a hysteresis controller offers a significant advantage in this area. Since electric vehicles now dominate the vehicle market, a reliable control system will eventually become even more important. In these electric vehicles, hysteresis controllers are used for a variety of purposes, including controlling the motor's speed, torque, and current to improve system efficiency. In addition, the hysteresis controller plays a significant role in this project. The SAPF results contain precision and quick reaction due to the specific regulator we utilized that is hysteresis controller. We used SAPF with hysteresis controller in this project to effectively and efficiently reduce harmonics. Additionally, we were able to mitigate the undesirable harmonics. The efficient use of energy, which is crucial for any business, comes with improved power quality. For better outcomes, improving power quality should be a major topic of discussion and consideration. Additionally, numerous technologies are currently being developed to continuously improve power quality.

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