A REVIEW OF HARMONIC ANALYSIS AND MITIGATION TECHNIQUES USING FILTERS

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Abstract

Nonlinear loads draw non sinusoidal current and voltage from the utility.These non-sinusoidal current and voltages created due to nonlinear loads are called harmonics.The harmonic voltages and current disturbs the system back and creates big power quality problem.Therefore in order to mitigate harmonic problems different mechanisms are used.Here as introduction different power quality problems, harmonics and their mitigation techniques/filters are presented and discussed.Between the different ways to minimize/eliminate harmonics active power filters are most prominent one.

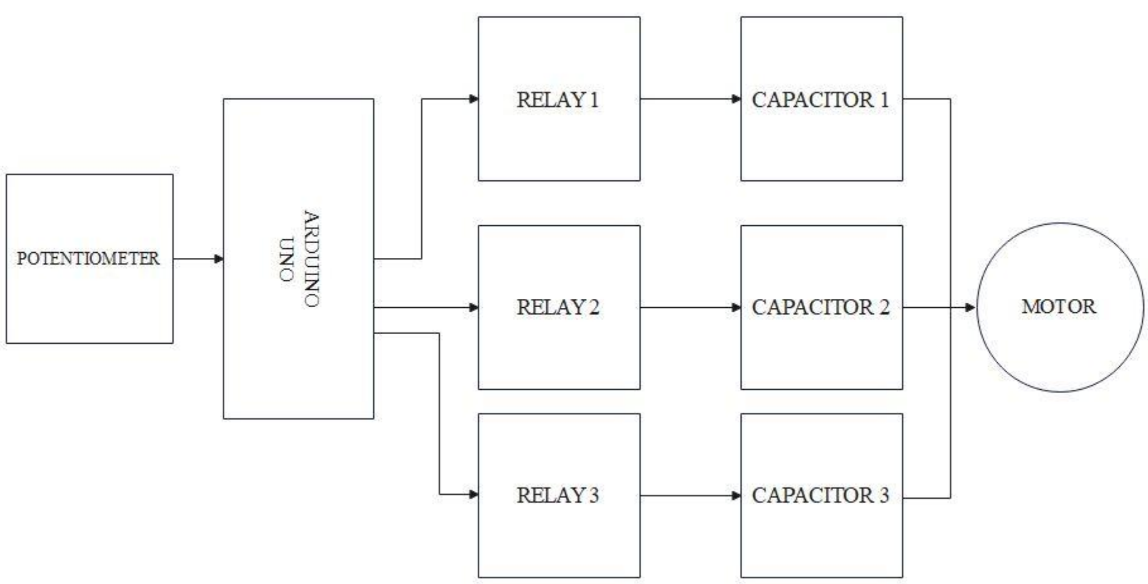
Keywords: *Filter, Mitigate harmonics*

Introduction

Power Quality is gaining increasing attention in the electric power industry. The consumer of electrical energy requires electric power with a certain quality, but loads can have a negative impact on the electrical system and are thus also subject to an assessment in terms of quality. Power quality is therefore linked to the interaction between the electrical system and loads and must take into account both the voltage quality and power quality.

A shunt-connected APF with a self-controlled dc bus has a topology comparable to a static compensator (STATCOM) used in power transmission systems for reactive power compensation. SAPF adjusts for load current harmonics by injecting compensating current that is equal but opposite in harmonic. In this situation, the SAPF acts as a current source, injecting the load's harmonic components but phase altered by 180 degrees [1]. Shunt active filters work on the basis of injecting current harmonics into the point of common coupling. This technique uses a three-phase, three-level diode clamped multilevel inverter to decrease source current harmonics. As in standard space vector PWM, the proposed pulse width modulation (PWM) scheme produces the inverter leg switching times using sampled reference phase voltage amplitudes and centers the switching times for the middle vectors in a sampling interval (SVPWM)[2]. For nonlinear loads, a shunt hybrid active power filter with both active and passive filters connected in parallel is designed to reduce harmonics on the source side. A tuned RLC circuit in the shunt passive filter acts as a band-pass filter for specific harmonic content. 19 Based on Clarke's transformation, the shunt active filter is usually a voltage source inverter (VSI) that creates a reverse harmonic current. To construct a Shunt Hybrid Active Power Filter (SHAPF) for a nonlinear load, the control method is done utilizing instantaneous reactive power theory. The proposed controller on shunt hybrid active power filter reduces total harmonic distortion (THD) of source current from 30.35 percent to 3.25 percent, according to the results. SHAPF outperforms the competition [3]. This study presents a survey of the most commonly used harmonic solutions as well as some innovative technology. The benefits and drawbacks are discussed, as well as the most common passive, active, and hybrid systems. As the number of non-linear devices connected to the network grows. There are several solutions to this problem; however, not all of them are appropriate in all cases [4]. Different passive filter designs are presented in this research to minimize harmonics in an industrial distribution system. The single tuned and double tuned harmonic filters are the passive filters discussed. The passive elements of the filters are derived during the design process. The effects of changing the lord parameters and the power factor correction capacitor on harmonic distortion are also explored. When compared to single-tuned filters, simulation findings demonstrate that the double-tuned filter is more effective at reducing harmonics [5].

BLOCK DIAGRAM:

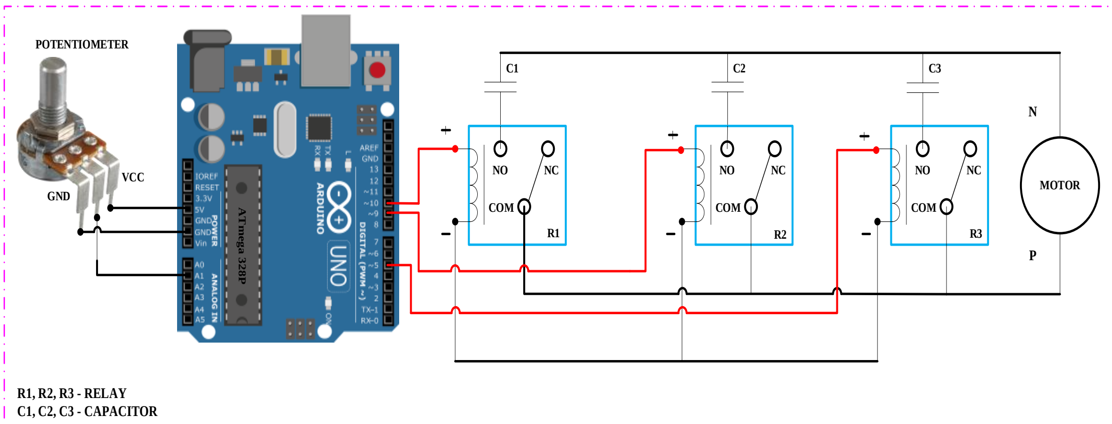


- Each relay is connected with the individual capacitor which is connected to the motor.
- Supply to the relay is given from the Arduino Uno.
- Potentiometer is given as the analog input of the Arduino.
- The relay is turned on based upon the input given by the potentiometer.
- When the relay is turned on, the capacitor connected with the respective relay turns on.
- Thus, the power factor of the motor gets improved.

CIRCUIT DIAGRAM:

- V_{cc} pin of the potentiometer is connected to the 5V of the Arduino.
- GND pin of the potentiometer is connected to the GND of the Arduino.
- The output of the potentiometer is given analog input A1 of the Arduino.

- The positive supply pin of the relay R1, R2 and R3 is given to the digital pins 10, 9, 5 of the Arduino.



- The negative supply pin of the relays R1, R2 and R3 are shorted.
- The common terminals of the relays are connected with the motor’s phase.
- One end the capacitor is connected with the **NO** terminal of the corresponding relay (C1-R1, C2-R2, C3-R3) and the other end is connected with the motor’s neutral.

PROPOSED METHODOLOGY:

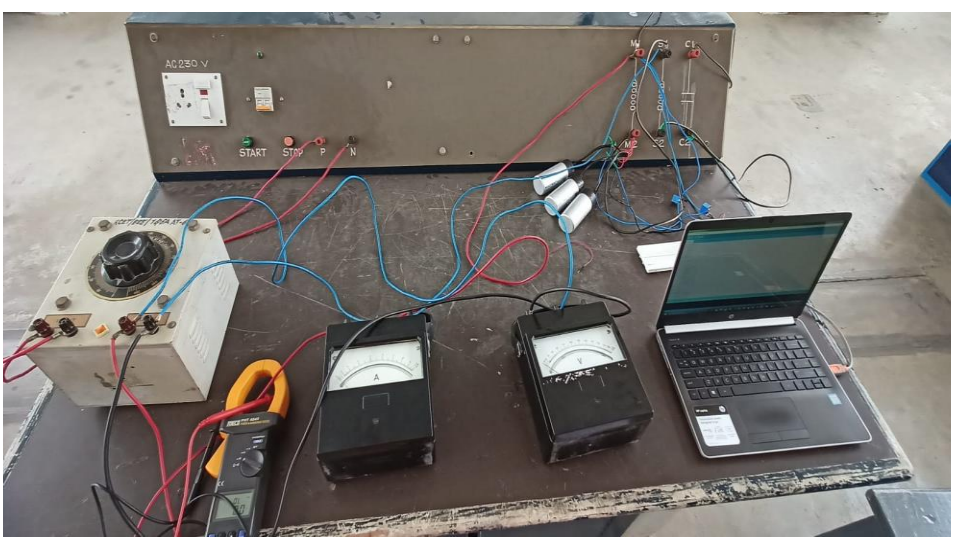


Fig:1 Hardware connection

- The capacitor is connected across the M1 and M2 terminals of the single phase induction motor.
- The implementation of capacitor improves the power factor of the motor.

MACHINES LAB – RESISTIVE LOAD:

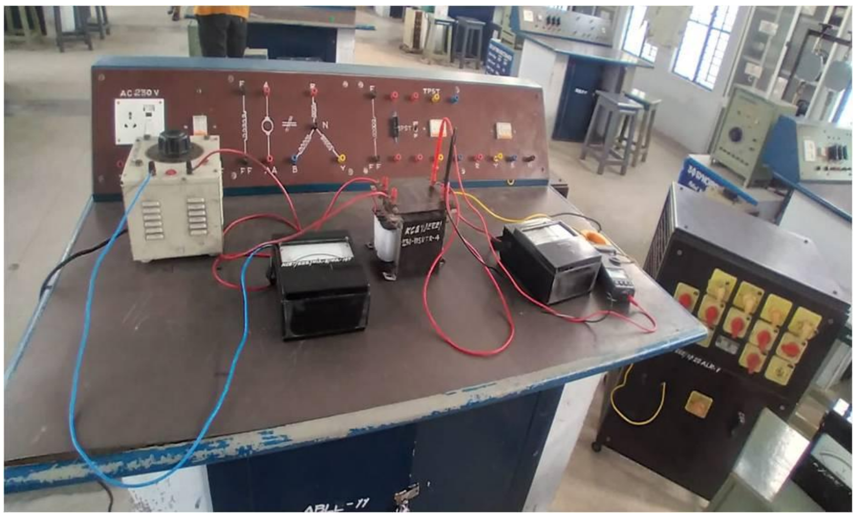


Fig:2 Hardware Connection of motor with resistive load

The given above figure is the hardware connection of the motor with resistive load.

The measured harmonics from the motor with resistive load is tabulated in the table given below.

The value of THD% is upto **7 %**.

Table:1 Harmonic Measurement under NoLoad

NO LOAD			
ORDER	**V**	**HARMONICS %**	**THD %**
1	125.5	100	4.4
3	20.3	0.3	7
5	21.1	1.1	4.6

MACHINES LAB (INDUCTIVE LOAD IN ALTERNATOR) :

Fig: 3Hardware Connection of Alternator with inductive load

Table:2 Harmonics - Alternator with inductive load

	Y	**PHASE**	
ORDER	**V**	**HARMONICS %**	**THD %**
1	4.2	100	28
3	0.5	10.5	28.1
5	0.3	4.5	27
7	0	4.3	28.6

SOLAR GRID TIE INVERTER:

PV Input Power = 50.30W

Grid Power=4800W

Grid Current R=7.12 A

Y=7.25A

B=7A

Grid Frequency = 49.9Hz

Grid Voltage R=239.5V

Y=241.8V

B=238.8

R PHASE:

Table:3 Harmonics – Solar Grid Tie Inverter(R Phase)

I=7A **THD=25.8%**

ORDER	**HARMONICS %**	**THD %**
1	100	0.5
2	5.4	0.4
3	3.8	0

4	2.8	0.3
5	2.1	0
6	0.5	0
7	6.9	0.6
8	4.1	0.4
9	3.5	0
10	6.7	0.5
11	16.9	1.3
12	1.5	0
13	9.1	0.8

Y PHASE:

Table:4 Harmonics – Solar Grid Tie Inverter(Y Phase)

I=7.1A THD=28.9%

ORDER	**HARMONICS %**	**THD %**
1	100	6.7
2	4	0.4
3	3.1	0.3
4	4.8	0.4
5	5.5	0.3
6	3.1	0
7	5	0.4
8	6.2	0.5
9	0.8	0
10	11.1	0.8
11	15.5	1.4
12	0.8	0
13	11	0.9

B PHASE:

Table:5 Harmonics – Solar Grid Tie Inverter(B Phase)

I=7.3 A THD=26.77%

ORDER	**HARMONICS %**	**THD %**
1	100	7
2	4	0.4
3	2.9	0
4	2.5	0.3
5	3.1	0.3
6	2.3	0
7	5	0
8	2.3	0
9	0.6	0
10	6.5	0.5
11	20.5	1.4

I

12	2.8	1.4
13	11.0	0.8

Table 3,4,5 shows the readings of R,Y and B phase respectively.

THEORETICAL CALCULATION:

To find active power demand:

25*0.99 =*24.75kW*

To find required compensation from filter:

24.75*tan[acos(0.99)] = *3.526kVar*

To find equivalent reactance(capacitive X_{filt}):

$X_{filt} = X_{cap} - X_L$ (at fundamental frequency)

$X_{filt} = kV^2(1000)$

$kvar = \frac{0.415^2(1000)}{3.526} = 48.84\ \Omega$

For tuning at the 4.7^th harmonic,

$X_{cap} = h^2 X_L = 4.7^2 X_L$

To find desired capacitive reactance(X_{cap}):

$X_{cap} = \frac{X_{filt}h^2}{h^2-1} = \frac{48.84(4.7^2)}{4.7^2-1}$

$= 51.155\ \Omega$

To achieve this reactance at 415V rating, the capacitor would have to be rated,

$kvar = \frac{kV^2(1000)}{X_{cap}} = 3.366kvar$

Now filter will be designed for 415V/5kvar,

$X_{cap} = \frac{0.415^2(1000)}{5} = 1.7226\Omega$

Rated capacitor current,

$I_{cap,rated} = \frac{5*10^3}{\sqrt{(3*415)}} = 141.7A$

Equivalent capacitive reactance,

$X_{L(fund)} = \frac{X_{cap}}{h^2} = \frac{34.445}{4.7^2} = 1.559\ \Omega$

$L = X_{L(fund)} = \frac{1.559}{2\pi*50} = 4.96\ mH$

$C = \frac{1}{2\pi\sqrt{LC}} = 0.9247\ \mu F$

The above theoretical calculation is the design ofLC filter where the values of L and C are calculated for the Solar Grid Tie Inverter in Y phase. The value of THD% in Y phase is upto 28.9 % which is tabulated in the table.

MACHINES LAB - SINGLE PHASE INDUCTION MOTOR (NO LOAD & WITH LOAD):

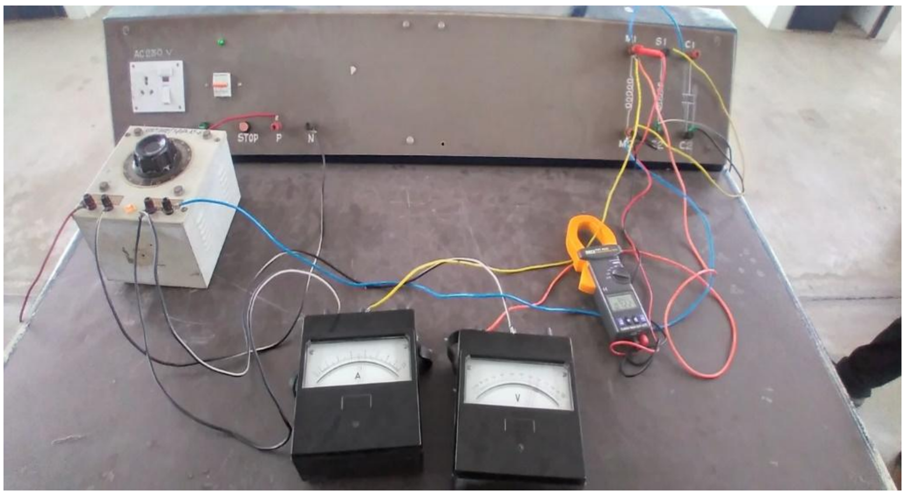


Fig: 4 Hardware Connection of Single-Phase Induction motor

The Figure given above is the hardware connection of Single-phase induction motor with and without load.

The measured voltage and current harmonics from the motor with and without load is displayed in the following tables.

VOLTAGE HARMONICS

Table:6 VoltageHarmonics – 1 **Ø** Induction motor (No Load) **V=215V**

NO LOAD			
ORDER	**V**	**HARMONICS %**	**THD %**
1	214.5	100	4.6
2	21.5	0.8	4.5
3	20.5	0	4.6
4	21.5	0.8	4.5
5	23.7	1.9	4.7
6	20.1	0	4.6
7	20.9	0.3	4.5

The measured **voltage** harmonics from the single-Phase induction motor in **no load** is tabulated in the table.The value of THD% is up to 4**.7 %**.

Table:7 VoltageHarmonics – 1 **Ø** Induction motor (With Load)**V=209.6V**

	LOAD=6A		
ORDER	**V**	**HARMONICS %**	**THD %**
1	209.6	100	4.6
2	21.3	0.7	4.7
3	20.7	0.3	4.8
4	21.5	0.8	4.5

I

5	23.4	1.6	4.7
6	2.02	0	4.4
7	20.7	0.3	4.6

The measured **voltage** harmonics from the single-phase induction motor with a **load of 6A** is tabulated in the table given above**.** The value of THD% is up to 4**.8%**.

The measured **current** harmonics in the single-phase induction motor in no load is tabulated in the table.The value of THD% is up to 7.7 **%**.

CURRENT HARMONICS:

Table:8 CurrentHarmonics **–** 1 **Ø** Induction motor (No Load)**I=5.4A**

NO LOAD			
ORDER	**CURRENT**	**HARMONICS %**	**THD %**
1	5.4	100	7.7
2	0	1.7	7.3
3	0	1.4	7.4
4	0	1.8	7.2
5	0	1.9	7.3
6	0	0.9	7.5
7	0	0.6	7.6

The measured current harmonics in the single phase induction motor in no load is tabulated in the table. The value of THD% is up to 7.6 **%**.

The measured current harmonics in the singlephase induction motor with a load of 6A is tabulated in the table**.** The value of THD% is up to 7.4 **%**.

Table:9 CurrentHarmonics **–** 1 **Ø** Induction motor (With Load)**I=5.8A**

LOAD = 6A			
ORDER	**CURRENT**	**HARMONICS %**	**THD%**
1	5.8	100	7.2
2	0	1.9	7.3
3	0	2.3	7.4
4	0	1.2	7.2
5	0	2.2	7.3
6	0	1.1	7.4
7	0	0.5	7.1

Next, we measured harmonics in an alternator in machines laboratory. The hardware connection of an alternator with inductive load is in Figure.

The tabulated readings of the alternator in Y phase are tabulated in the table given below table.

The value of THD % is upto 28.6%.

RESULTS AND DISCUSSION

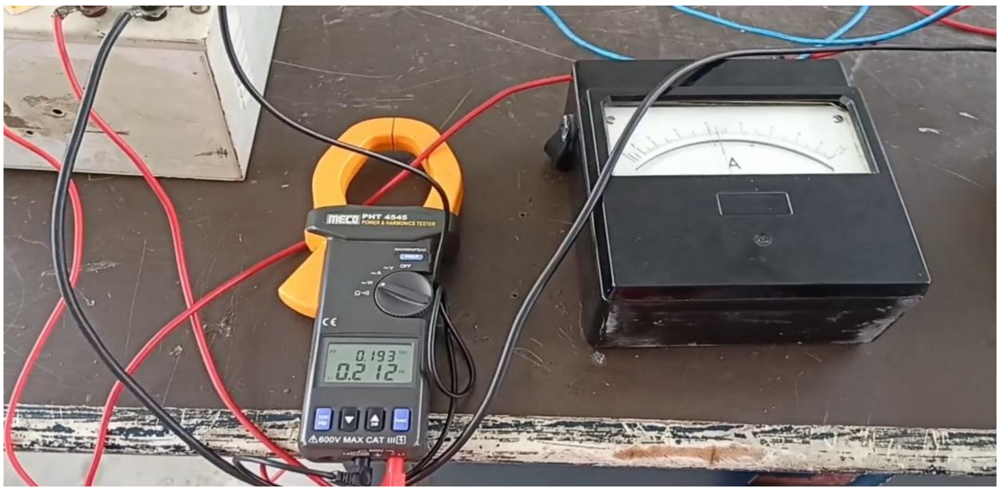


Fig: 4 Power factor before turning on the relay(No load)

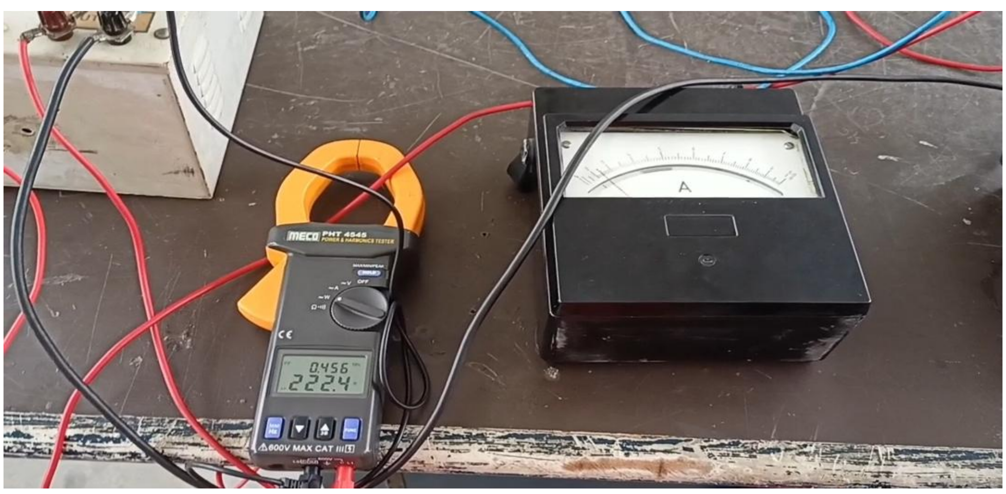


Fig: 5Power factor after turning on the relay(No load)

The harmonics makes power loss in the line. So, the ultimate aim is to reduce the harmonics there by increasing the power factor. Based on analysis and recommended solution is using three 20 micro farad capacitor. The value of power factor is 0.123 in no load condition before turning on the relay (i.e.) before adding capacitor. After the relay is turned (i.e.) addition of capacitor, the power factor is improved from 0.123 to 0.456.It can be inferred that the power factor is improved. Addition of an inductor with the capacitor of suitable values forms an LC filter which can mitigate the harmonics.Thus, the power factor is improved, which reduces the loss and improves the power quality of the machine.

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