White paper on Active Harmonic Filter

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1) Background:

The importance of power quality is increasing day by day in global scenario. In India, the subject is still at a nascent stage.

Initiatives on the economic reforms front from Government of India, has lead to development of Industries & Infrastructures across the board, especially the IT Industry which was the first to boom since 1997.

The power sector in India couldn’t cope up with the economy growth, due to which the consumers are forced to use backup source of power such as DG Sets & UPS . The Energy conservation initiatives made consumers to invest on power saving devices such as VFD, High efficiency lamps, process optimization through Automation etc.

The use of computers, servers in IT Industry are causing problems such as over loaded neutral, increased neutral to earth voltage, nuisance tripping of circuit breakers etc due to Third harmonic.

The use of energy conservation equipment such as VFDs, Thyristor controlled heaters, UPS etc.. are causing various problems at consumer end such as tripping of DG set, failures of capacitor banks, over heated induction motors, nuisance tripping of relays etc due to negative sequence harmonic generated by 6 pulse converters.

This paper is intend to discuss the basics of Active harmonic filters, practical application of Active Harmonic filters for effective harmonic mitigation.

2) Active Harmonic Filter:

Advancement in Power Electronics has lead to various applications of semiconductor devices.

In good old days, the harmonic filtering was made using the following technology:

- Passive filters.
- Dual winding transformers for 12 pulse.
- Zigzag transformers
- 24 Pulse technology.
- Lower system impedance etc.

All the above have one common factor - **high capital investment.**

Each of the above technologies has advantages & limitations. **The limitations in terms of performance, augmentation, investment have lead to invention of Active based compensation.**

2.1) Active harmonic filter basics:

The Active Filter technology represents a breakthrough in the mitigation of harmonic problems by effectively eliminating the critical limitations of the conventional Passive Filters.

The wide variety of features of this technology, enable the user to easily achieve a reliable solution for reduction / elimination of harmonics combined with optional variable reactive power compensation. Some of the salient features of active filters are listed below:

- Incorporation of high end insulated gate bipolar transistor (IGBT) switching technology to generate required frequency spectrum
- Use of advanced digital signal processors (DSPs) to enable real time control
- Elimination of 'L-C impedances' in the principle of filtering
- Immune to network frequency changes / variations
- Can be installed at any location
- Easy capacity enhancement due to modular design
- Optional control of reactive power compensation

PRINCIPLE OF THE ACTIVE FILTER

The active filter is based on the principle of measuring the harmonic currents and using this measurement on a real time basis to generate a harmonic current spectrum in phase opposition to the measured spectrum. This has the effect of canceling the original harmonic currents. **Figure 1** illustrates the principle of the active filter.
The active filter uses a CPU (Central Processing Unit) for detecting the order and magnitude of the harmonics present in the load and injects a compensating current on a real time basis. The CPU can also determine the extent of reactive power compensation to be made available for power factor correction.

The control system is such that it is necessary to choose only the current rating of the filter out of several standard ratings available. **Extensive knowledge of the network is generally not required as in the case of passive filters.**

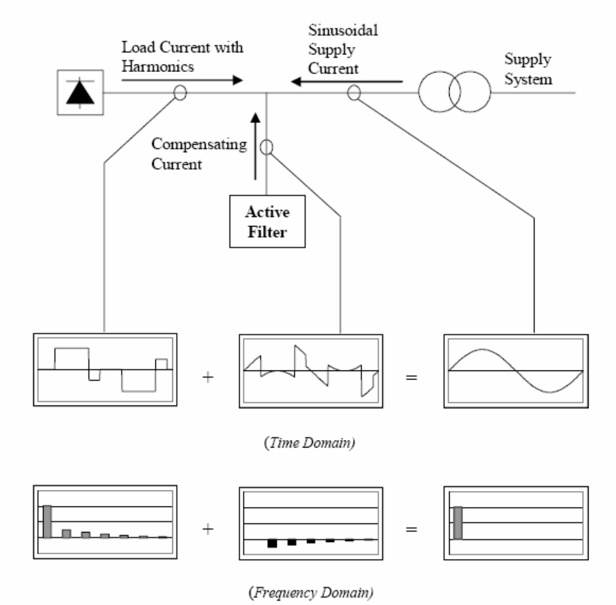
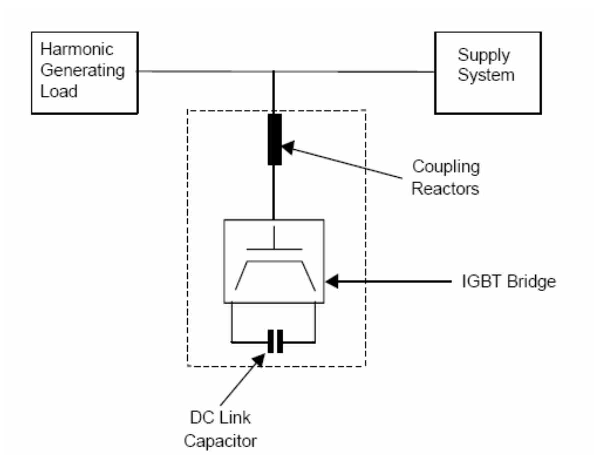


Figure -1

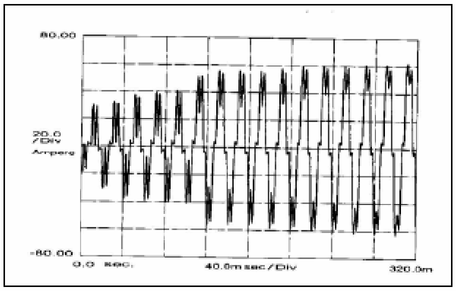
COMPONENTS OF THE ACTIVE FILTER

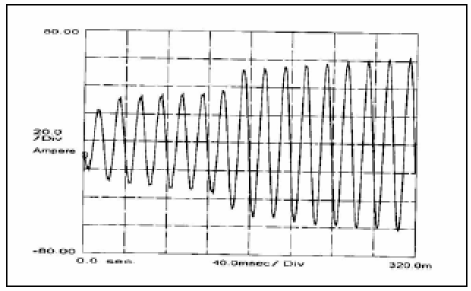
The active filter monitors the line current in real time and converts the data to digital signals in a Central Processing Unit (CPU). The current generator and the control system are the key elements of the active filter. The compensating current is generated by an IGBT bridge that can generate any required waveform using Pulse Width Modulation (PWM) technology. The source for the IGBT Bridge is a DC link capacitor which is charged simultaneously with the generation of compensating current to the network. The generated output is injected into the network via a reactor / filter circuit. The principle of connection is shown below.



ACTIVE FILTER OPERATION

The waveforms recorded in respect of a lift drive during acceleration mode are shown below.





It can be observed that the active filter is able to remove the distortion and achieve a sinusoidal wave shape as seen from the supply side.

Active filters can be easily connected across individual loads or alternatively connected on the supply bus.

Since Active Filters are modular by construction, the ability to reduce distortion can easily be enhanced by adding more filters in parallel.

CONCLUSION

The harmonic spectra resulting in low voltage installations have become more complex due to wide variety of power electronic loads. The amplitude of various harmonics present has also become a dynamic variable due to increasing time-varying characteristics of modern power electronic loads.

While PASSIVE FILTERS have been used effectively in the past, and will continue to be used in very specific applications, their limitations in the context of low voltage applications have now become an important issue.

ACTIVE FILTERS have therefore emerged as the new generation solution for mitigating harmonic problems in low voltage networks.

Given the modular design, elimination of network analysis, ease of adapting to changing network conditions, and coupled with the fact that they are environmentally friendly products, ACTIVE FILTERS represent a reliable, user-friendly "Plug & Play" solution for solving harmonic problems.

:CASE STUDIES:

3.1) **IT Industry:**

3.1.1) Problem Description:

The IT Industry has installed with 300kVA x 3 nos, UPS for critical loads such as Servers, computers etc.

The output of the UPS is connected to Raising mains busbar system, the protection system involves the following:

- Earth Leakage Circuit breaker (ELCB).
- OCR / EFR
- UV / OV relays.
- ACB.

The raising mains will distribute the output power of UPS to all 5 floors in the building.

Each floor is having dedicated Distribution board (DBs). The DBs are feeding Computer / servers in each floor level.

The main problem experienced by the customer is:

- Neutral current at each floor is about 120Amps, the phase current is only 80 to 90A.
- The neutral current at UPS output is about 500Amps.
- Over heating of neutral.
- Nuisance tripping of ELCB.

3.1.2) Problem Analysis:

A comprehensive harmonic audit was carried out, following are the analysis of problem.

The load on the DBs are mainly single phase computer / servers. The computers are categorized as SMPS loads that generate significant magnitude of 3^{rd} harmonic.

The third harmonic being zero sequence in nature will add up arithmetically in neutral conductor, consequently the neutral current will increase.

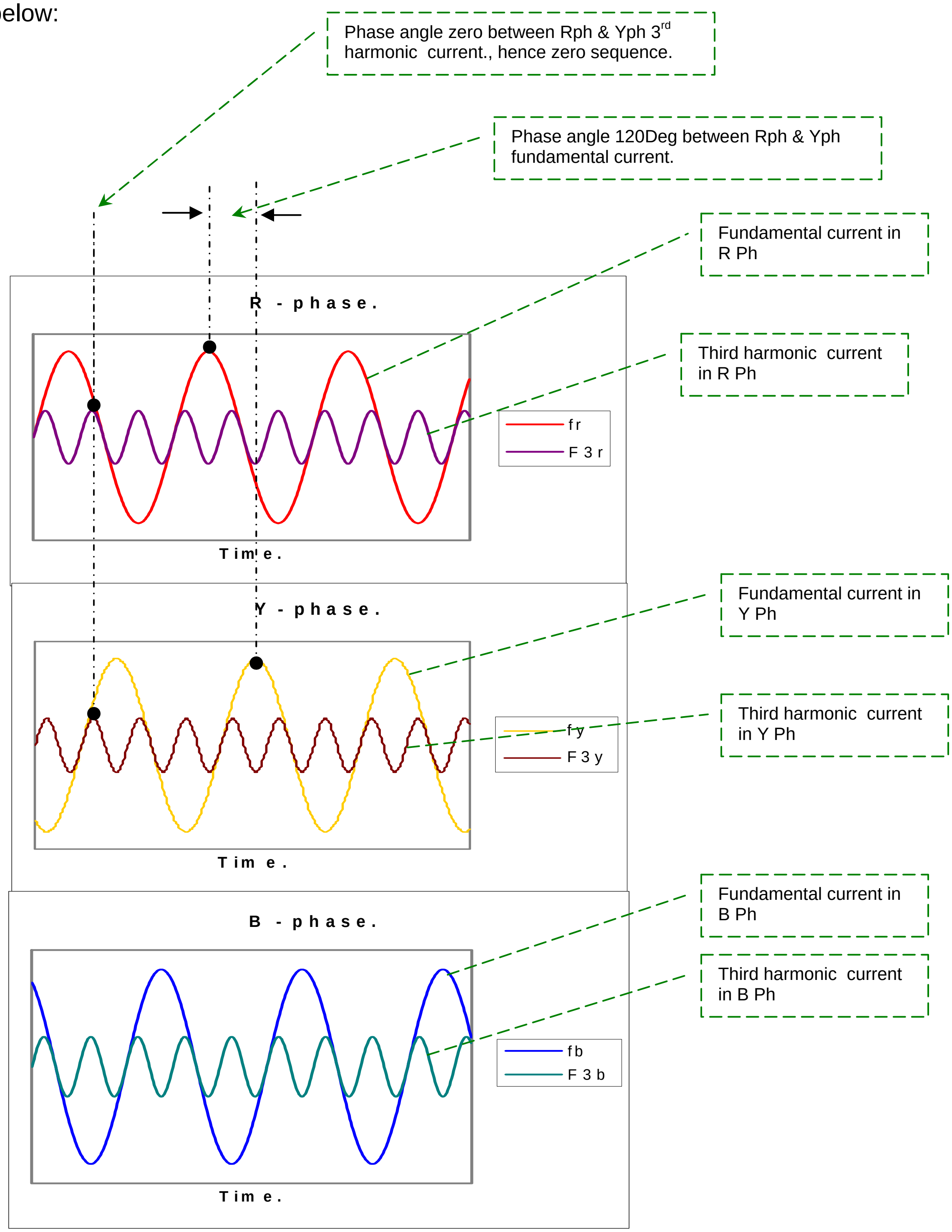
3.1.2.1) Why Neutral current is high:

Triplen harmonics falls under the category of odd harmonics having frequencies that are multiples of 3 E.g., 3, 9, 15, 21…. These harmonics are quite common in LT installations because of extensive use of single-phase non-linear loads such as Computers, Servers, Data centres etc.

Almost all the loads that make use of SMPS as a power source at the input side generated Triplen harmonic. In the spectrum, the third harmonic will be dominant followed by 9^{th} & 12^{th}.

3.2.2.2) Why Third harmonic is Zero sequence?

Consider a three phase 4 wire network feeding Computer loads, the input voltage waveform and the individual phase Fundamental and 3rd harmonic current waveforms are depicted below:

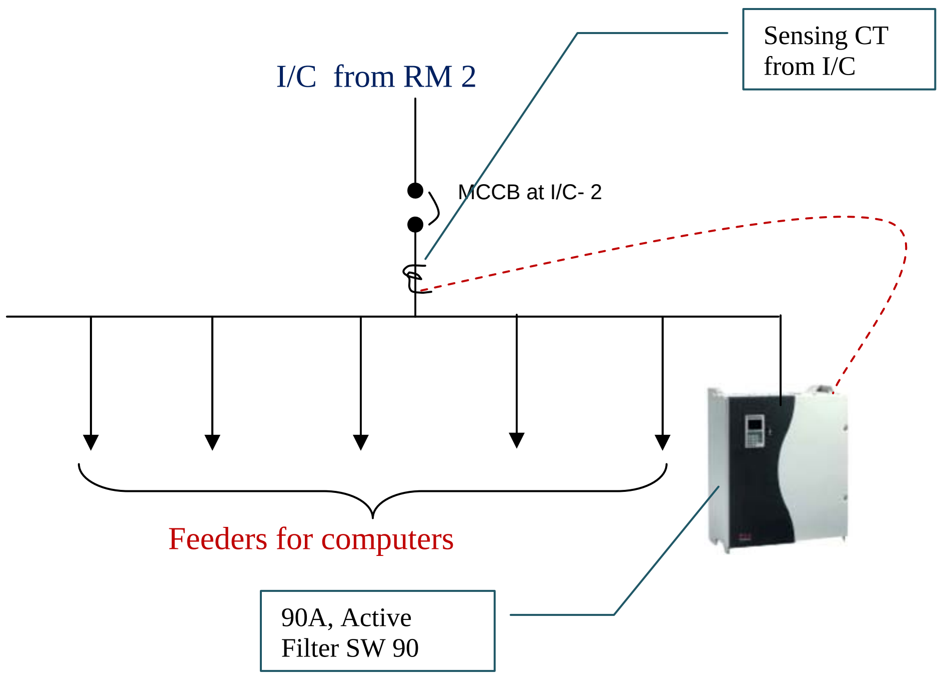


As the third harmonic wave is exactly in phase in all three phases, will add up arithmetically in neutral, consequently the neutral current will be more than phase current.

3.1.3) Solution:

The neutral current at each floor was about 120Amps with 95% of Third harmonic current.

The solution involved providing 90A, 3ph, 4 wire SineWave Active Harmonic filter (Schneider make) at each floor DB Level, so that the harmonic is controlled at floor level itself as shown below:



3.1.4) Validation – After Installation:

Readings at 1st Floor				
Description	Without Filter	With filter	Savings in Amps	Savings in kVA
Ir-Amps	79	71	8	1.8
Iy-Amps	66	60	6	1.4
Ib-Amps	73	66	7	1.6
In-Amps	**97**	**12**	**85**	**4.8**
Readings at 2nd Floor				
Description	Without Filter	With filter	Savings in Amps	Savings in kVA
Ir-Amps	61	51	10	2.3
Iy-Amps	78	64	14	3.2
Ib-Amps	70	58	12	2.8
In-Amps	**109**	**11**	**98**	**8.3**
Readings at 4th Floor				
Description	Without Filter	With filter	Savings in Amps	Savings in kVA
Ir-Amps	77	60	17	3.9
Iy-Amps	63	52	11	2.5
Ib-Amps	68	55	13	3.0
In-Amps	**113**	**9**	**104**	**9.5**
Readings at 5th Floor				
Description	Without Filter	With filter	Savings in Amps	Savings in kVA
Ir-Amps	71	58	13	3.0
Iy-Amps	74	60	14	3.2
Ib-Amps	74	59	15	3.5
In-Amps	**119**	**4**	**115**	**9.7**

3.2) **Glass Manufacturing Industry:**

3.2.1) Problem Description:

The plant is installed with Thyristor controlled Resistive furnaces. 1000kVA DG used as backup source of power in case of Grid failure.

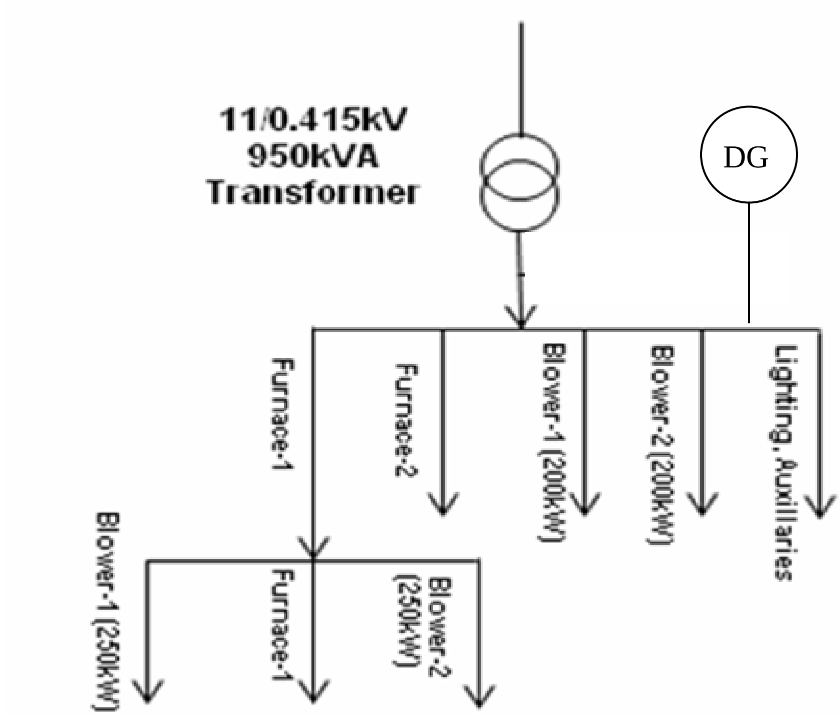
Whenever the DG is used to feed furnaces, the customer is facing following problems:

1. Increased Humming noise in the DG.
2. Increased Voltage flickering.
3. Tripping of DG without indications

3.2.2) Problem Analysis:

A comprehensive harmonic audit was carried out, following are the analysis of problem.

The Furnace is a 6 pulse type, and generates significant magnitude of 5th harmonic current. The 5th harmonic is categorized as negative sequence in nature, due to which the DG will have negative torque on the shaft.



Following are the measurement taken at the input side of DG.

Feeder Name	Voltage V	Current A	Power Factor	% VTHD	% ITHD	% I3	% I5	% I7	% I11	% I13
DG Incomer	416	756	0.98	5.5	17	3.7	14.1	8.6	2.9	1.11

The 5th harmonic current is about 14% and the RMS value of 5th harmonic current is about 106Amps.

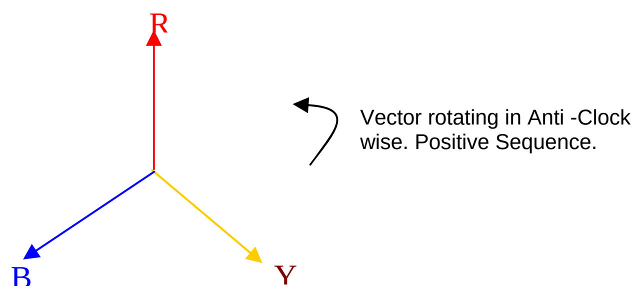
3.2.2.1) What is Negative sequence:

Fundamentally, in 3 phase Electrical system, there are three types of sequence in which the Voltage / Current vector follow:

1 Positive Sequence.
2 Negative sequence and
3 Zero sequence.

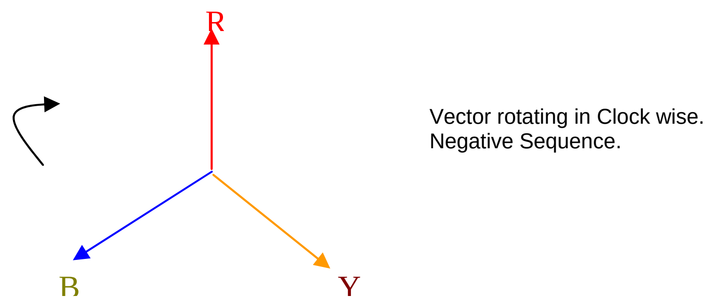
- Positive Sequence:

In positive sequence, the three phase vector will rotate in Anti-clockwise direction (convention) with a phase shift of 120 Electrical degrees as shown below:

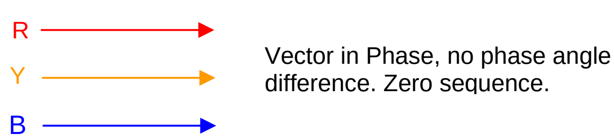


- Negative Sequence:

In Negative sequence, the three phase vector will rotate in clockwise direction (convention) with a phase shift of 120 Electrical degrees as shown below:



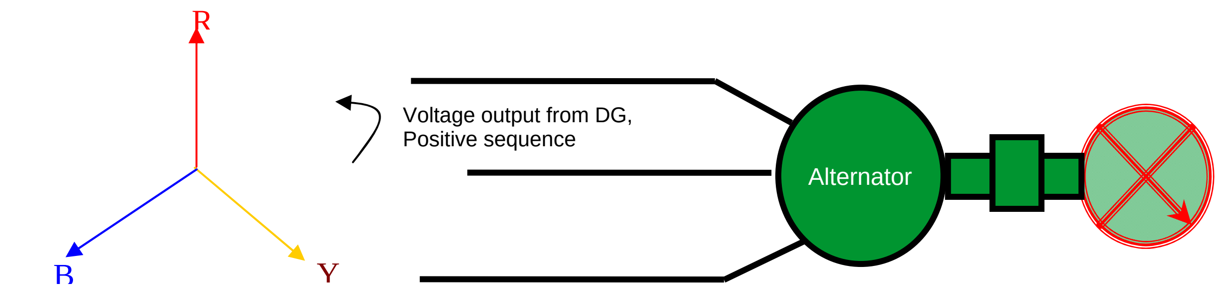
- Zero Sequence:

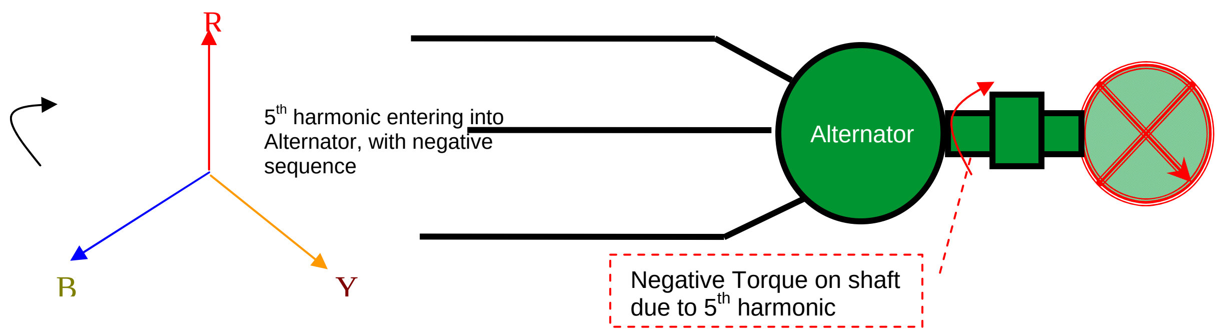


In zero sequence, the vectors in three phase will have zero degree phase shift, consequently the zero sequence component will add up Arithmetically in the neutral.

3.2.3) How negative sequence affects DG:

The basic problem in this case is the negative torque generated on the DG shaft due to 5th harmonic as described below:





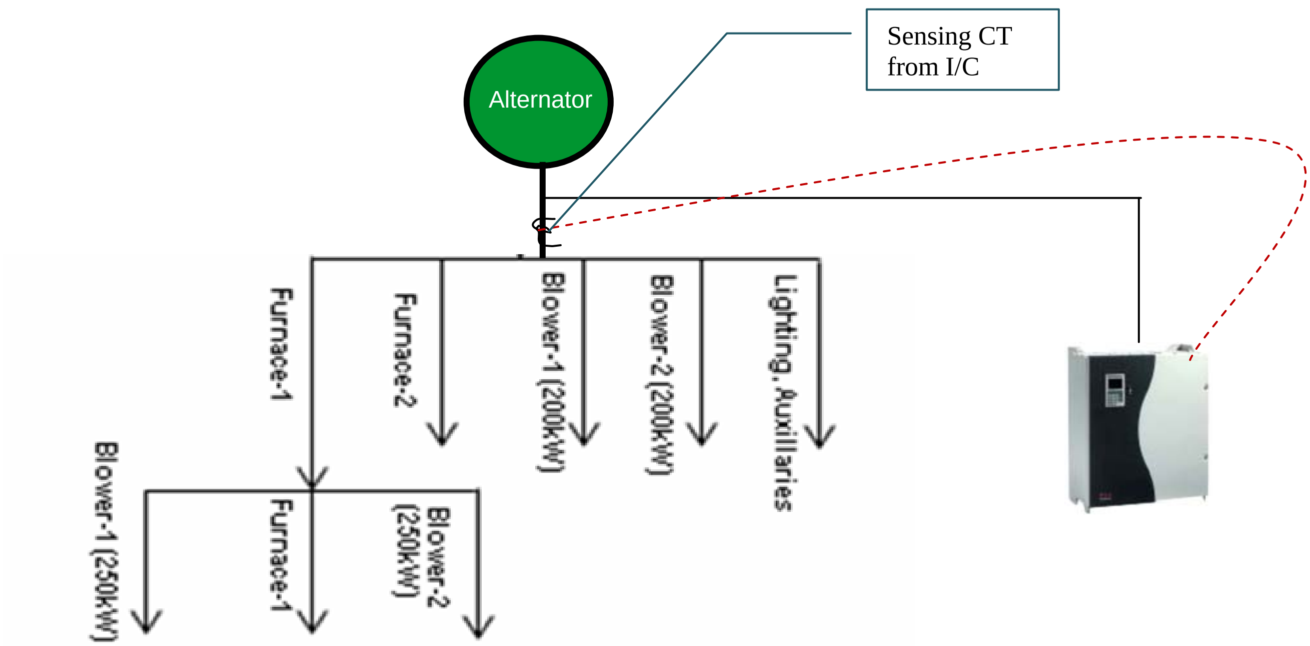
The above schematic represents the effect of negative sequence harmonic distortion on the DG set. The 5th harmonic being negative sequence will generate negative sequence magnetic Flux inside the Alternator winding, the negative sequence flux will generate negative torque on the shaft due to Armature reaction.

The negative (or reverse) torque will be transferred to the Engine causing flickering and nuisance tripping of DG.

3.2.4) Solution:

The passive based solution will have limitations to be used along with DG, as the PF may go to leading side that may cause malfunction in AVR used in DG set.

The ideal solution is to use Active harmonic filter at the Alternator output terminals, so that the harmonic generated by Furnace loads are filtered write at the alternator end.



3.2.5) Validation – After Installation:

Description	Voltage V	Current A	Power Factor	% VTHD	% ITHD	% I3	% I5	% I7	% I11	% I13
Without filter	416	756	0.98	5.5	17	3.7	14.1	8.6	2.9	1.11
With filter	416	725	0.98	2	3	1	2	1	1	1