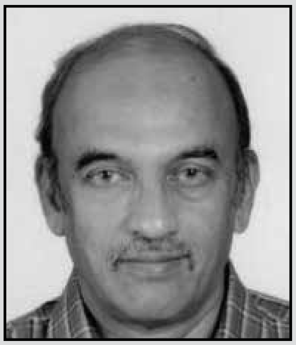
# Neutral Current Compensator (NCC): A Case Study for Hospital Load

Authors



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## Introduction

This is a case study for possible installation of a three-phase, 440 V, 16.67 A Neutral Current Compensator (NCC) panel for a Hospital in Jaysingpur. The NCC has several advantages which include compensation of neutral current near load, elimination of earth connection, reduction in deviation of phase to neutral voltages from average voltage, neutral loss reduction, keeping star point of supply transformer at earth potential irrespective neutral current amperes and earth resistance, and fit and forget installation due to the use of only magnetic components and if necessary use of certain capacitive kVAr to reduce voltage transients during single phasing. NCC can be designed and used for low to high voltage systems without use of any additional transformer. It is an economical and reliable solution to reduce neutral current in electrical distribution systems.

## Power quality study for the hospital in Jaysingpur

Annexure –I gives the test report for power quality study carried out for the 100 kVA, 11 kV / 440 V, 50Hz Distribution Transformer at the concerned hospital. The study is carried out on the secondary side of Distribution Transformer. Following are some observations based on the study of recorded data on KRYKARD ALM-35 make Power Quality analyzer.

**Annexure –II** gives observations based on the test report.

## Basic details of NCC and its installation for hospital in Sangli

The NCC is product for which patent is already applied by Shreem Electric Ltd., Jaysingpur and it can be installed at this hospital site.

Annexure –III gives basic details of NCC and also gives results for a working installation of an NCC at a hospital in Sangli. The load here is 30 kVA.

The installed NCC mentioned above has been working over one and half years. The hospital had problems related to deviated voltages (unacceptable deviations from average) because of which it could not commission imported medical equipment. The problem was solved by the installation of NCC and the same has been working satisfactorily for the mentioned period. The neutral current reduction for this installation can be seen from figures A4.1 and A4.2 in Annexure –III.

## Effects using NCC for the hospital load

It is important to know the effects of using an NCC along with Distribution Transformer and the same are discussed below.

The NCC incorporation is as shown in Annexure –IV. Note that either of connection Earth 1 or Earth 2 needs to be done. Both should not be done as it gives rise to circulating current in earth. The connection Earth 1 or Earth 2 allows the entire secondary side distribution system to have one single protective earth connection. Further, it should be noted that there is no current which can flow in this earth connection. Thus, even if the earth pit dries or develops high resistance the neutral or star point of the transformer secondary side remains at “Zero” potential with respect to earth (as there is no current flowing in the earth connection). This reduces voltage flicker in the load supplied voltages as there is no “shifting of neutral potential” with respect to earth..

The neutral connection from load comes to NCC as shown Annexure –IV. The NCC needs to be connected as near as possible to the load. For a single point load, like the hospital under consideration here, it is easier.

In the proposed hospital installation case, the 3rd harmonic in load current, and hence in the neutral current, is dominating. The NCC stops entry of this current in the supply neutral and thus current distortion and hence the supply voltage distortion is almost eliminated.

The NCC also should be able to reduce the deviation of load voltages by almost 50% from the average voltage as explained in Annexure –V.

In order restrict sudden over voltages when single phasing condition (one phase missing from supply) occurs, the NCC incorporates approximately 25% of load kVA as kVAr. This also helps in supplying reactive kVAr compensation usually required by the Distribution Transformer. The percentage of course can generally vary between 10 to 30% depending upon the type of load.

The simulation results for the present case of hospital under consideration while incorporating the NCC on the secondary side of the transformer are given in Annexure –V. These results reflect the above advantages.

The NCC incorporation should also give some of the advantages as discussed under Annexure –III (which are basic advantages of NCC).

## Summary of using NCC with the hospital load

The summary of using NCC along with hospital load under consideration and also in general using it along with a Distribution Transformer is as given below.

- Elimination of neutral current in star point of the transformer.
- No effect of earth resistance and maintains potential of star point of the transformer at “Zero Volts”. This eliminates possibility of voltage flicker in load voltages.
- Reduces current distortion and hence voltage distortion of the incoming supply voltages based on elimination of neutral current.
- Reduces copper loss in the transformer.
- Improves life of the transformer.
- Reduces possibility of load facing phase to phase voltages and effects thereof.
- Reduces deviation of load voltages from average voltage (by 50%). This helps sensitive load installations like hospitals.
- Reduces neutral loss as the NCC is connected close to the load.
- Virtually no maintenance as the NCC uses mainly passive and magnetic components.

Based on the above reasoning’s and presented details, the NCC (rating 12.7 kVA, three-phase, 50 Hz, 440 V, 16.67 A) is already installed at the Jaysingpur Hospital in first week of October 2014. It is working fine as desired.

This case though presented for a hospital load supplied by a Distribution Transformer can be extended to all linear as well as non-linear loads where neutral current or neutral potential shifting (and consequences thereof) is a prominent problem.

## Conclusion

A Neutral Current Compensator, based mainly on magnetics, is an economical way of reducing / eliminating unbalanced / zero sequence current flowing into supply network. It thus help in addressing "zero shifting" of star or neutral point of supply network, reducing deviations in phase to neutral voltages faced by the load apart from system loss reduction. The case study presented shows an effective way of achieving these results, should open ways to improve power supply quality, and help both the distribution supply agencies as well as the users.

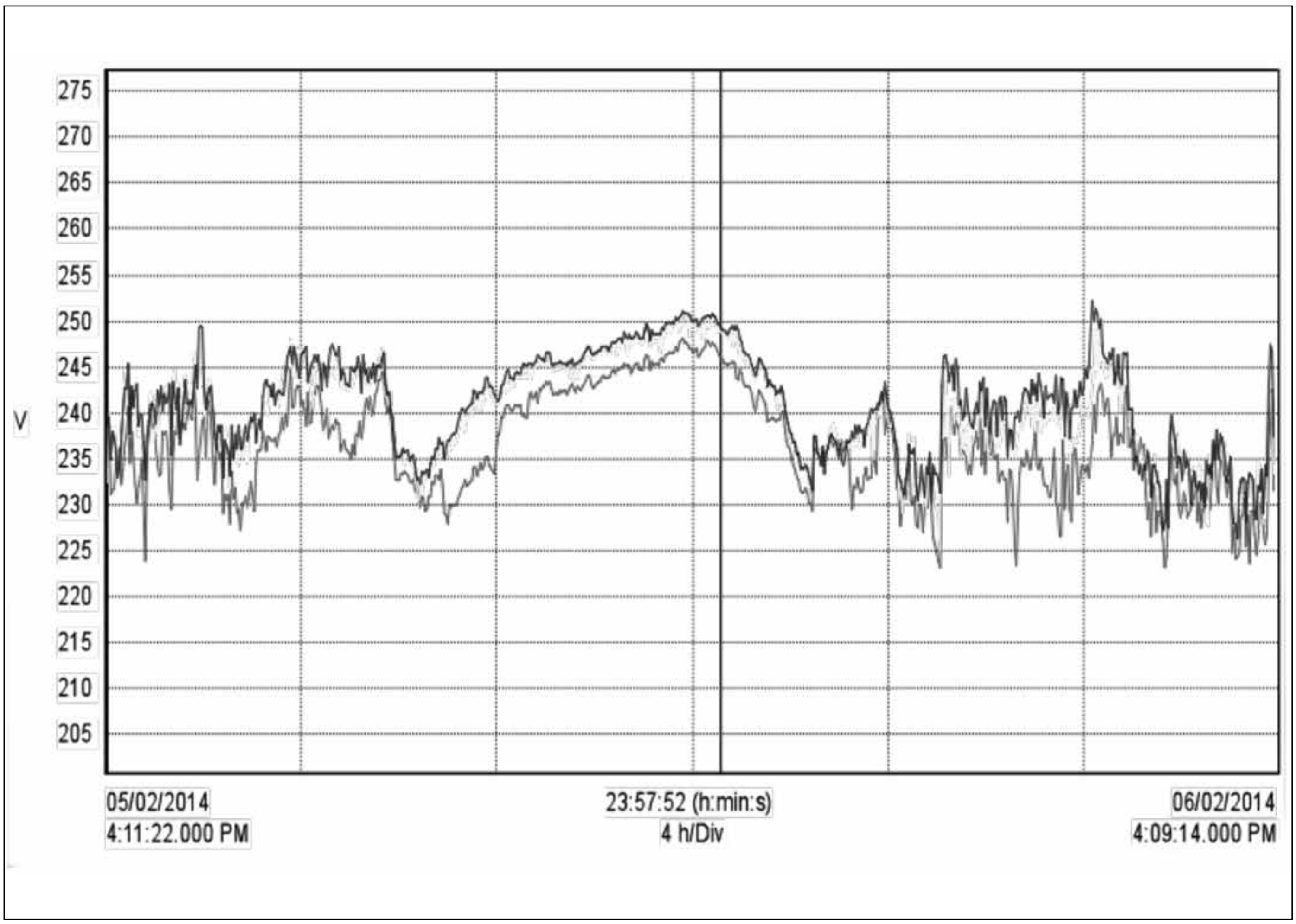
## Acknowledgement

The author acknowledges and thanks MSEDCL Jaysingpur as well as the concerned hospital Jaysingpur for their help and cooperation and the opportunity given to carry out power quality measurements and to install the NCC.

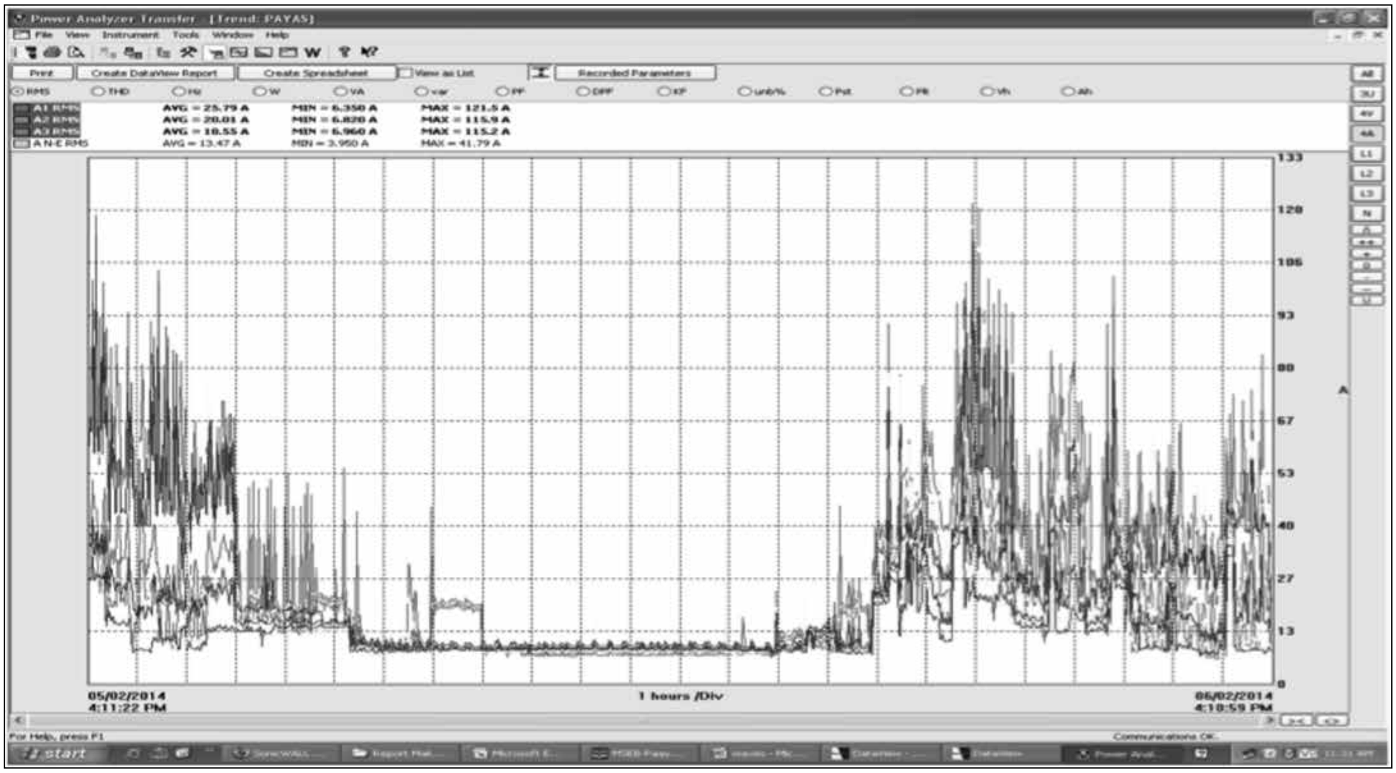
# Annexure –I

### Power Quality Test Report

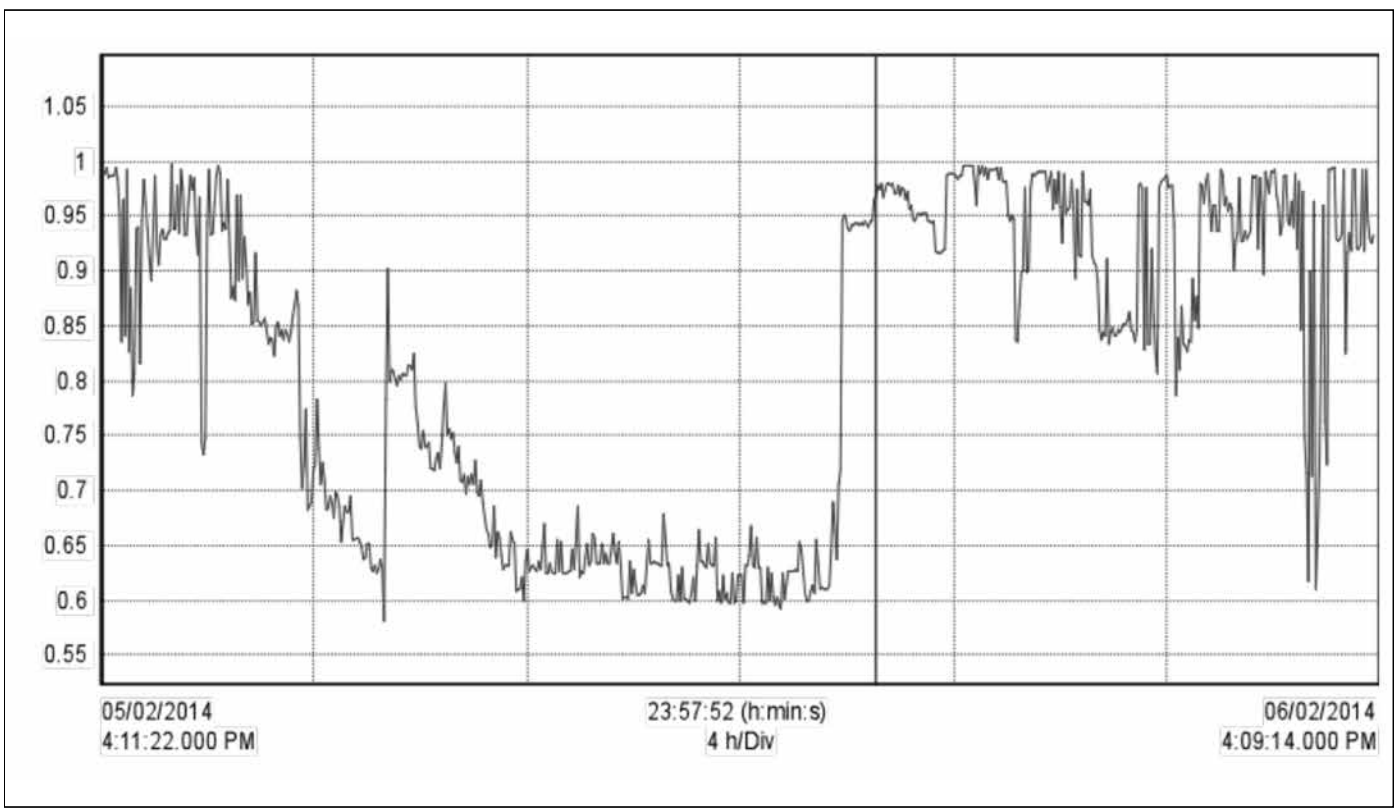
Recorded data is for 24 hours



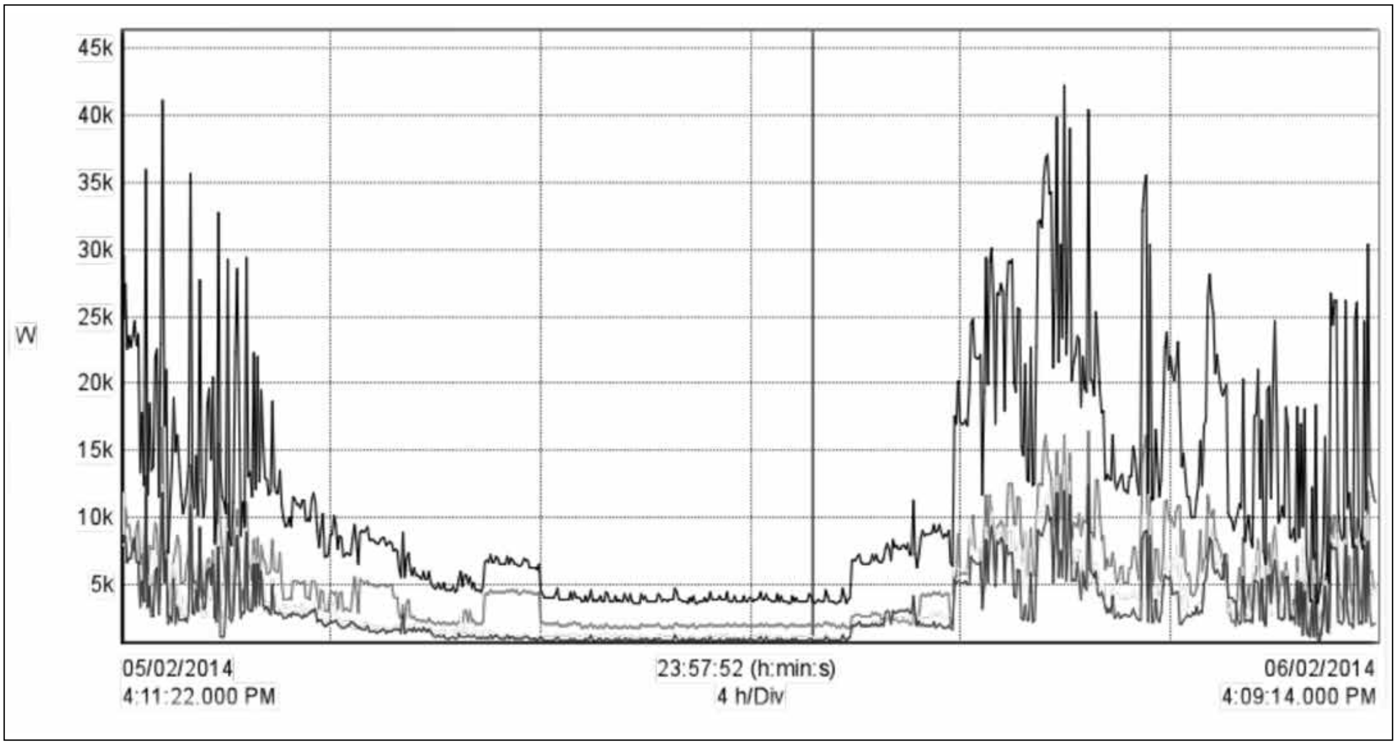

*Graph no.1 (Three-Phase Voltages)*



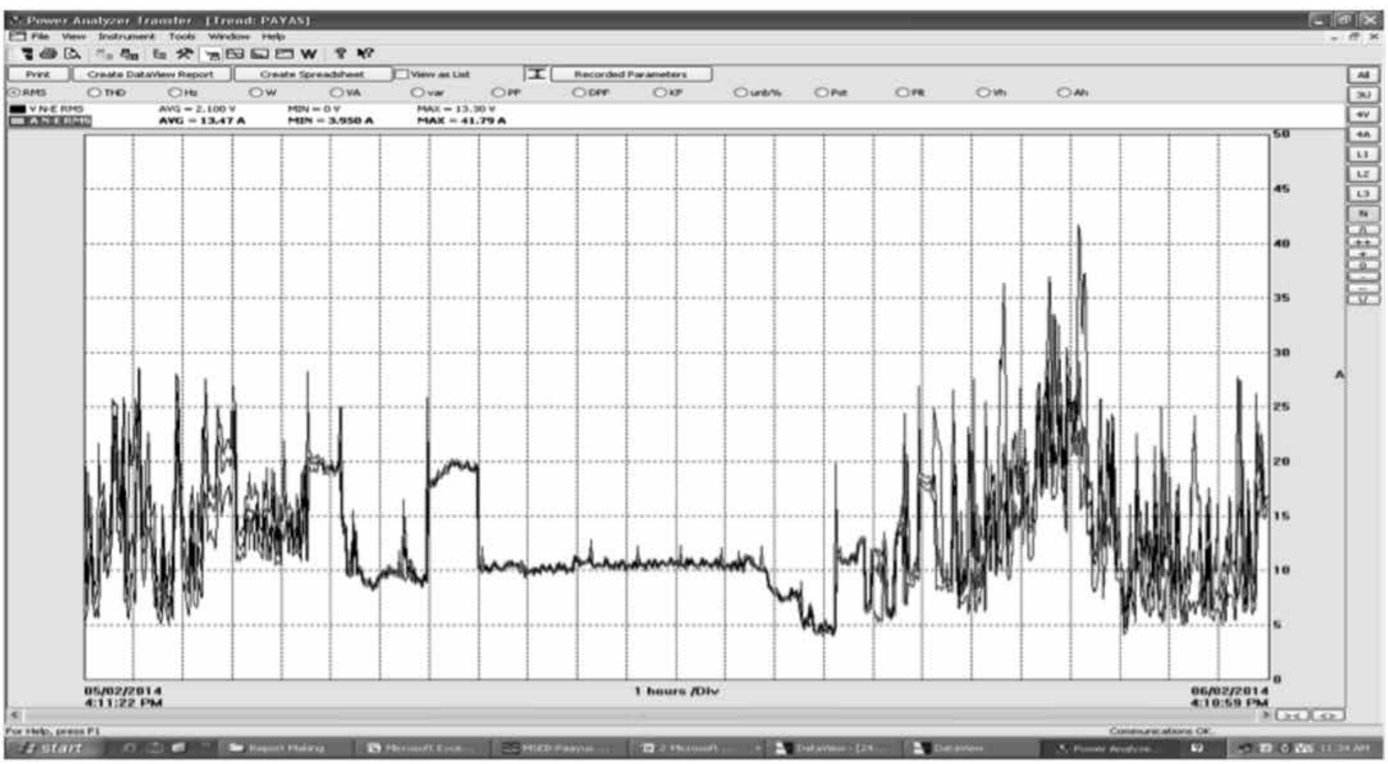

*Graph No.2 (Three-Phase Currents)*



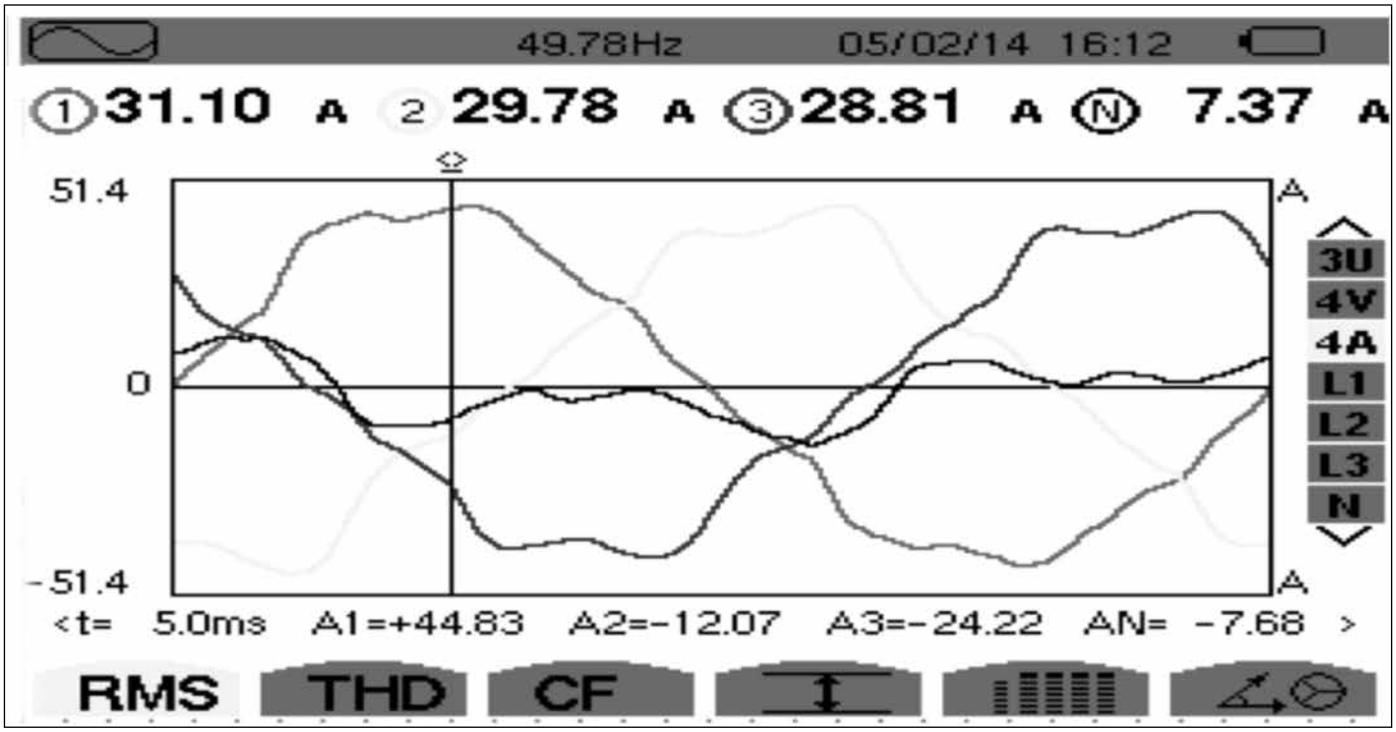

*Graph No.3 (Power Factor)*




*Graph No.4 (Active Power)*




*Graph No.5 (Neutral Current)*




*Graph No.6 (Three-Phase Currents and Neutral Current together)*

## Annexure –II

### Observations

1. Per phase voltage varies as 227-250 V. (Refer Graph No.1 of Annexure –I).
2. Maximum Current recorded per phase R-phase: - 121 A, Y-phase 115 A, B-phase 115 A This shows the load is clearly unbalanced. (Refer Graph No.2 of Annexure –I)
3. Power factor varies between -0.65 to 0.99 depending upon loading condition.(Refer Graph No.3 of Annexure –I)
4. Maximum Active power recorded is 43kW. (Refer Graph no.4 of Annexure –I)
5. Maximum Neutral current 41.6A is approximately 32% full load current of 100 kVA , 440 V transformer (Refer Graph No.5 of Annexure –I)
6. Voltage asymmetry with respect to average voltage 239V at maximum neutral current condition is R-phase 239-227=+12V; Y-phase 239-241= -2V, B-phase 239-249= -10V respectively.
7. Total current THD is 13.90% out of which 3rd harmonic is dominating (approximately 13.6%). This causes major distortion in current waveform and hence also for the transformer secondary voltage.

## Annexure –III

### Basic details of NCC

**Simple and Reliable Solution Eliminates Neutral Current Problems in LV to HV Systems**

### Neutral Current Causes, Effects, and Mitigation

**Causes**

- Unbalanced Fundamental active and or reactive currents

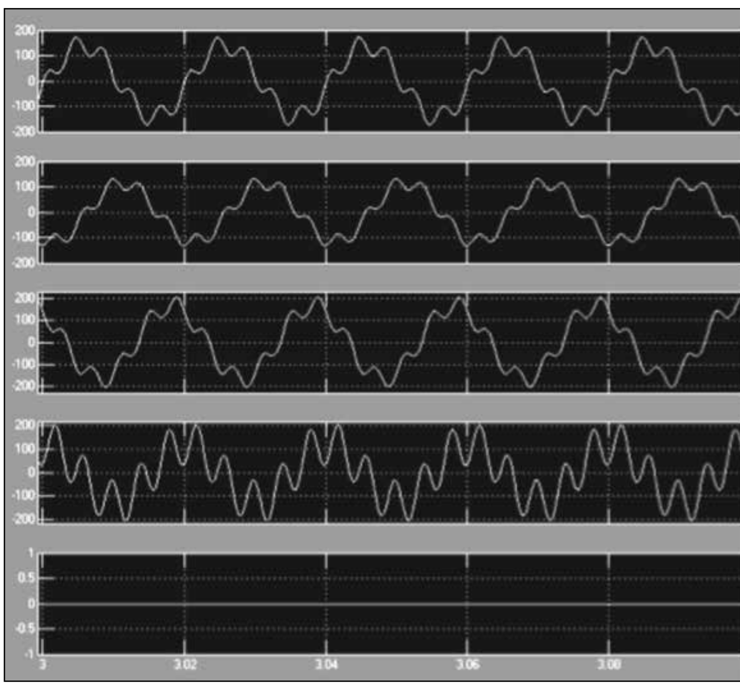
- Unbalanced current harmonics
  (drawn by non-linear loads in three-phase systems)

**Effects**

- Heating of neutral busbar or burning/ insulation failure of neutral cables
- Shifting of supply neutral potential with respect to earth potential based on earth resistance and the neutral current
- Unacceptable unbalance or asymmetry in phase to neutral voltages damaging sensitive loads such as in medical applications
- Disconnection from supply neutral point or earth resulting in phase to phase voltages appearing across loads and subsequently causing damage to loads (example: Tube Lights, Bulbs, Fans, TVs, Refrigerators, and other household appliances)
- Disturbances in synchronization voltages for connected active power converter
- Large unbalanced loads causing voltage disturbances to other loads connected on same bus, sometimes resulting in visible flicker
- Reduction in life of incoming supply transformer
- Associated monitory / financial loss due to non-availability of load

**Salient Features / Advantages of the NCC**

- Can be used for star as well as delta connected supply feeding power to star connected balanced / unbalanced and linear / non-linear load
- Reduces neutral current flowing in the supply (directly or through earth) to near zero value, irrespective of the type of non-linear load
- Helps in retaining supply neutral voltage (star point) close to earth or zero potential even when earth resistance is high (earth pit goes dry) or supply neutral point gets disconnected from earth or load neutral gets disconnected from supply neutral point or load neutral gets disconnected from earth
- Eliminates "performance" dependency of load neutral connection to supply neutral point or earth
- Reduces unbalance current caused by triplens as well as by other unbalance in other harmonics present in the load currents




Ch1, Ch2, Ch3: Line currents $i_a$, $i_b$, $i_c$ ($100^+$ to 200 A peak to peak)

Ch4: Uncompensated Neutral Current $i_{nL}$ (200 A peak to peak) of the load

Ch5: Compensated Neutral Current $i_{nNCC}$ (0 A) flowing out from the NCC

*Figure A3.1: Simulation results for unbalanced non-linear load*

- Reduces asymmetry in phase to neutral voltages (deviation from average value) by almost 50%, which further helps in reducing the unbalanced load neutral current.
- Uses only magnetic components offering high reliability
- Robust (fit and forget)
- Easy to manufacture, erect, and commission
- Very economical

## NCC Matlab Simulation Results

Refer figure A3.1.

## NCC Experimental Results for 30 kVA Unbalanced Load with NCC installed at a Hospital in Sangli

Refer figures A4.1 and A4.2.

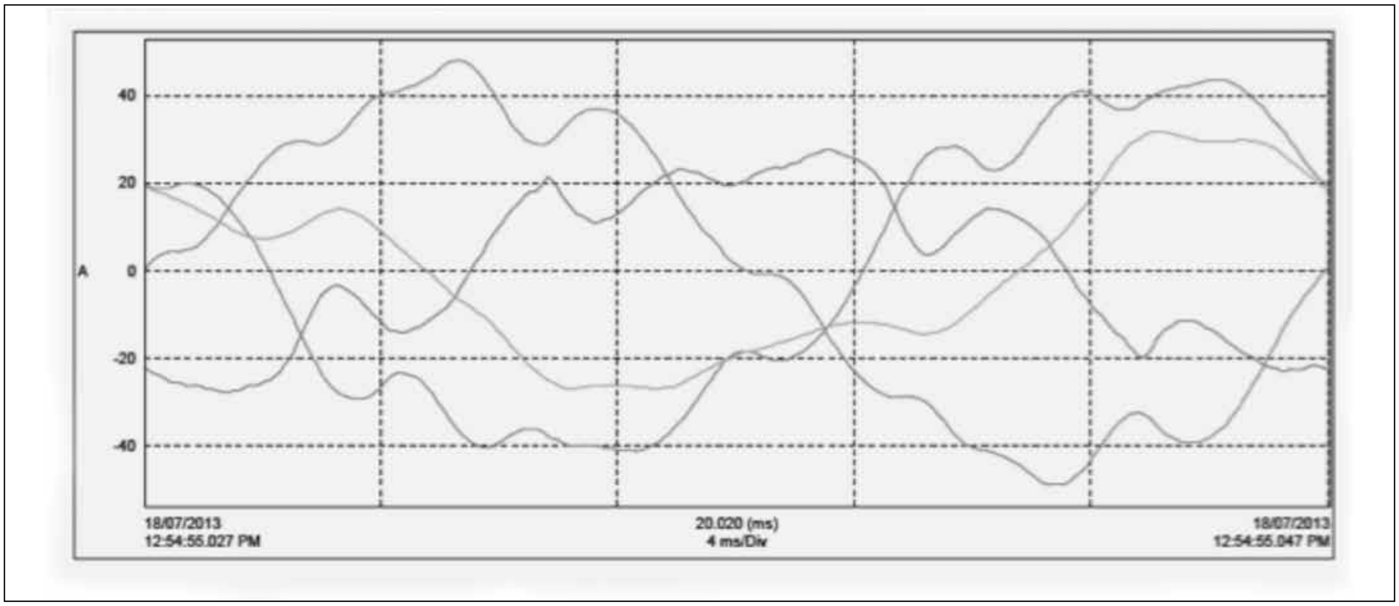



*Figure A4.1: The three load currents and neutral current shown by Green (with peak approaching 35 A without NCC installation) entering the supply neutral point*

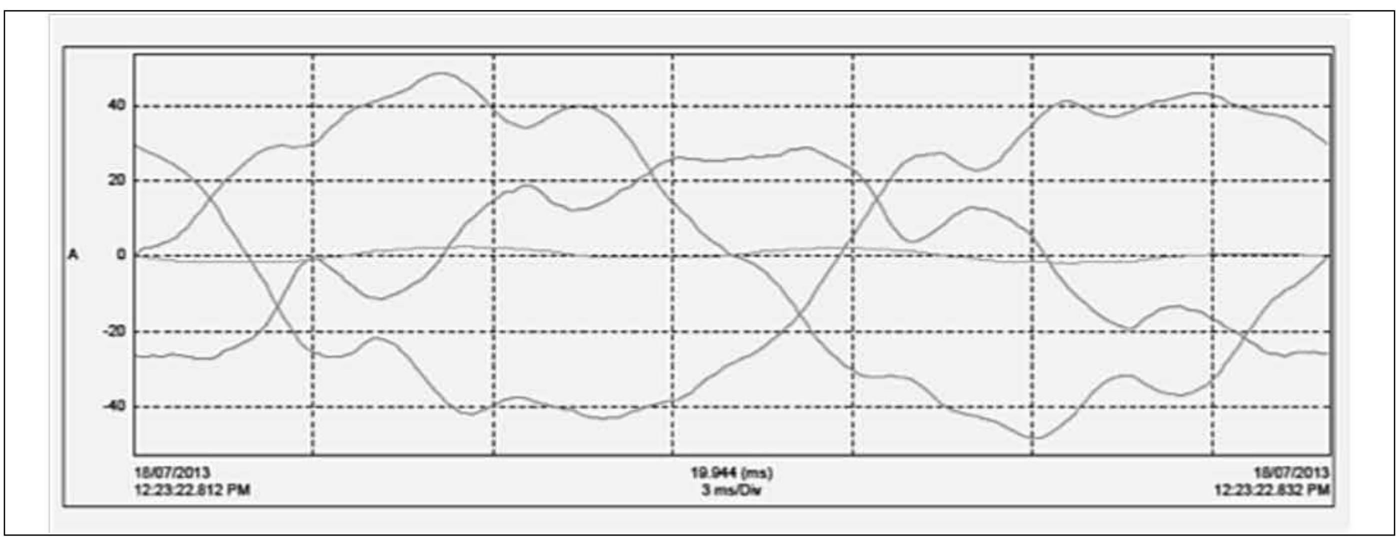
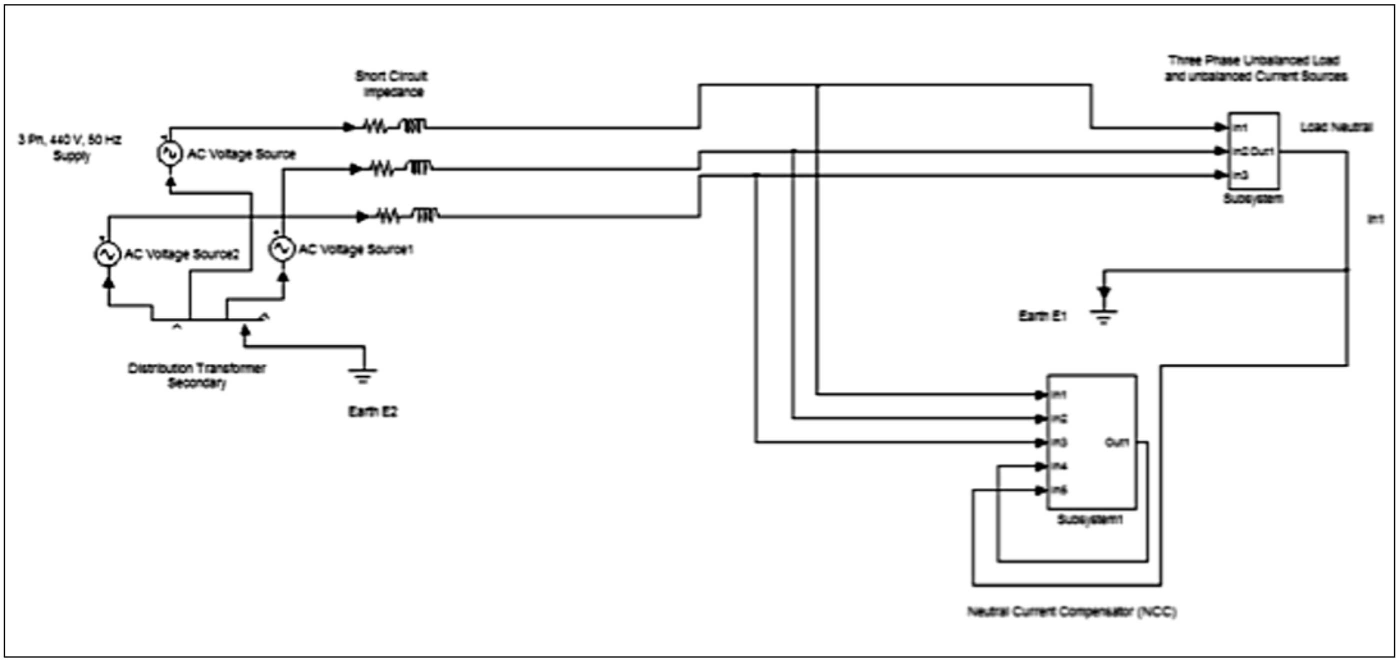



*Figure A4.2: The three load currents and neutral current shown by Green (almost close to zero with NCC installation) entering the supply neutral point*

# Annexure –IV

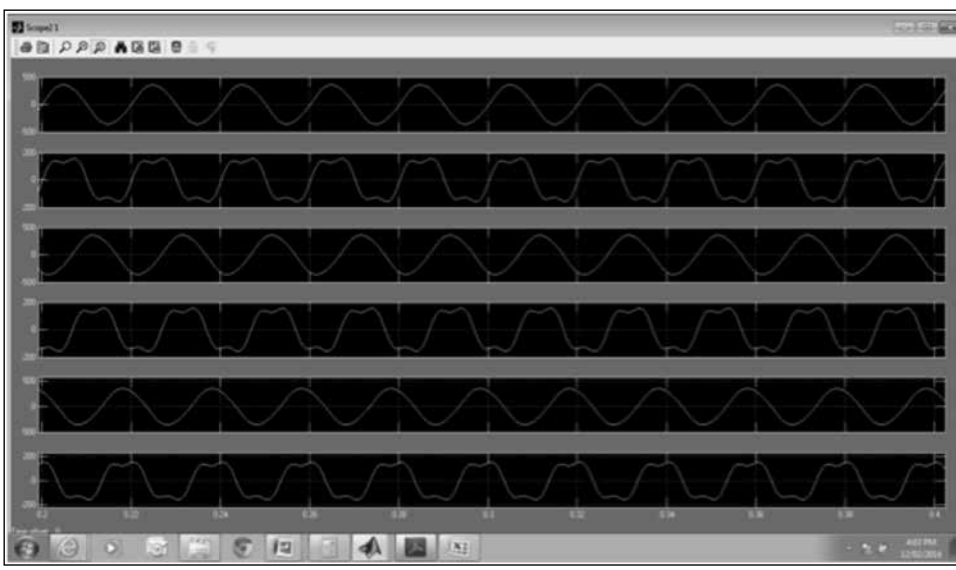
**Connection diagram for NCC with Distribution Transformer and non-linear load developing unwanted neutral current**




# Annexure –V

**Simulation results for the hospital case under consideration before and after incorporating NCC**

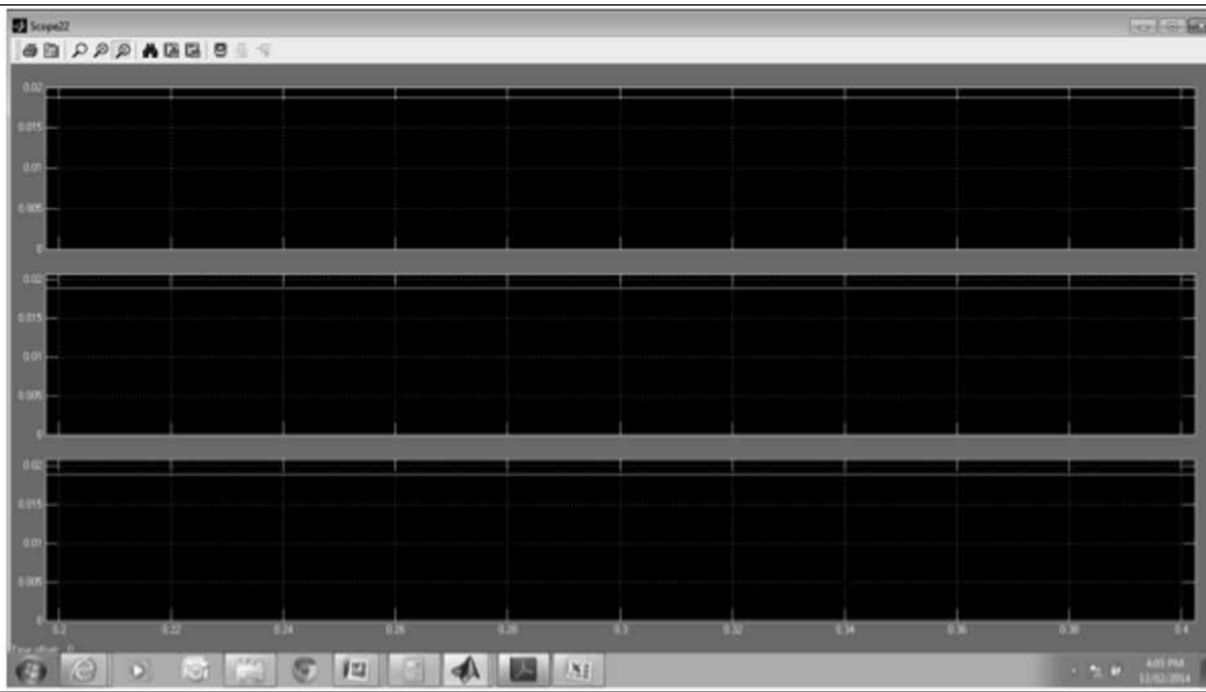
**"Without" connecting NCC**



**Ch1, Ch3, Ch5: Phase voltages**

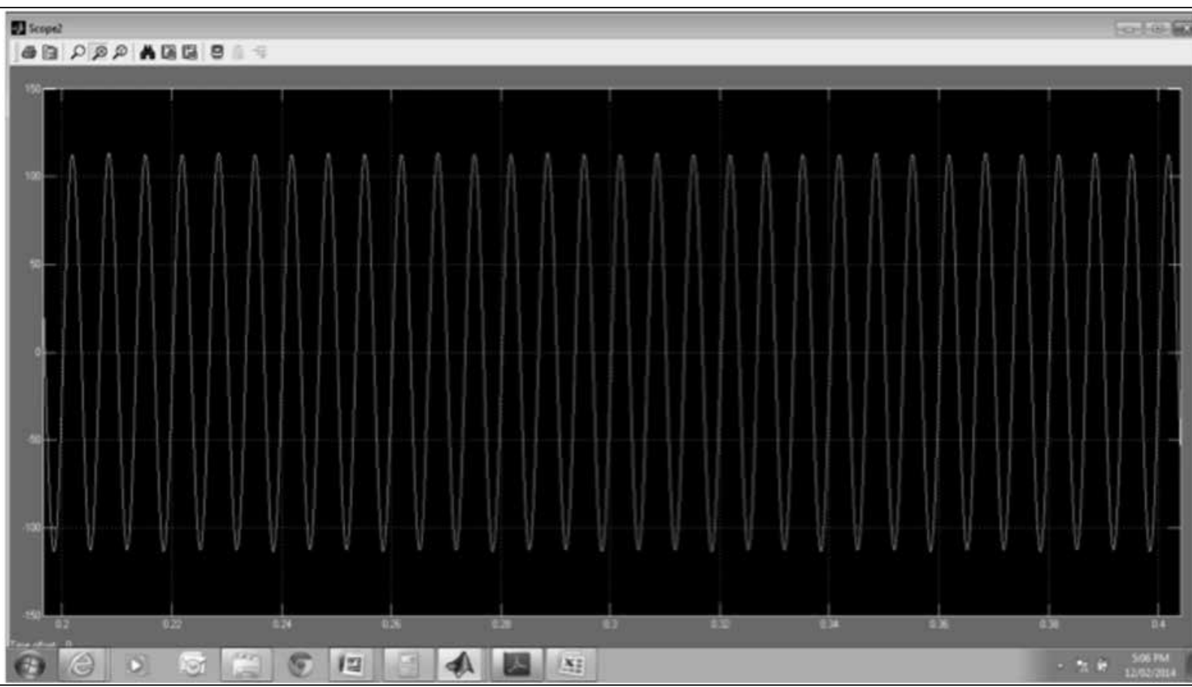
**Ch2, Ch4, Ch6: Phase currents**

**"Without" connecting NCC**



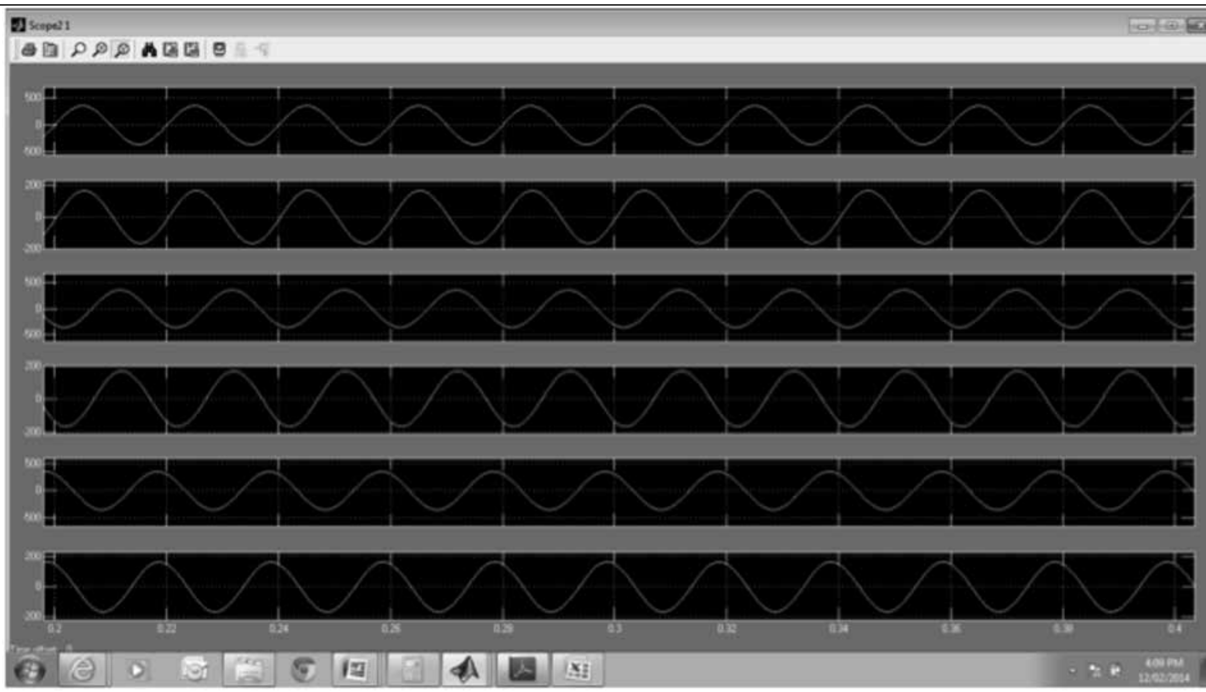
**Ch1, Ch2, Ch3: Phase current distortion (approximately 18%)**

**"Without" connecting NCC**



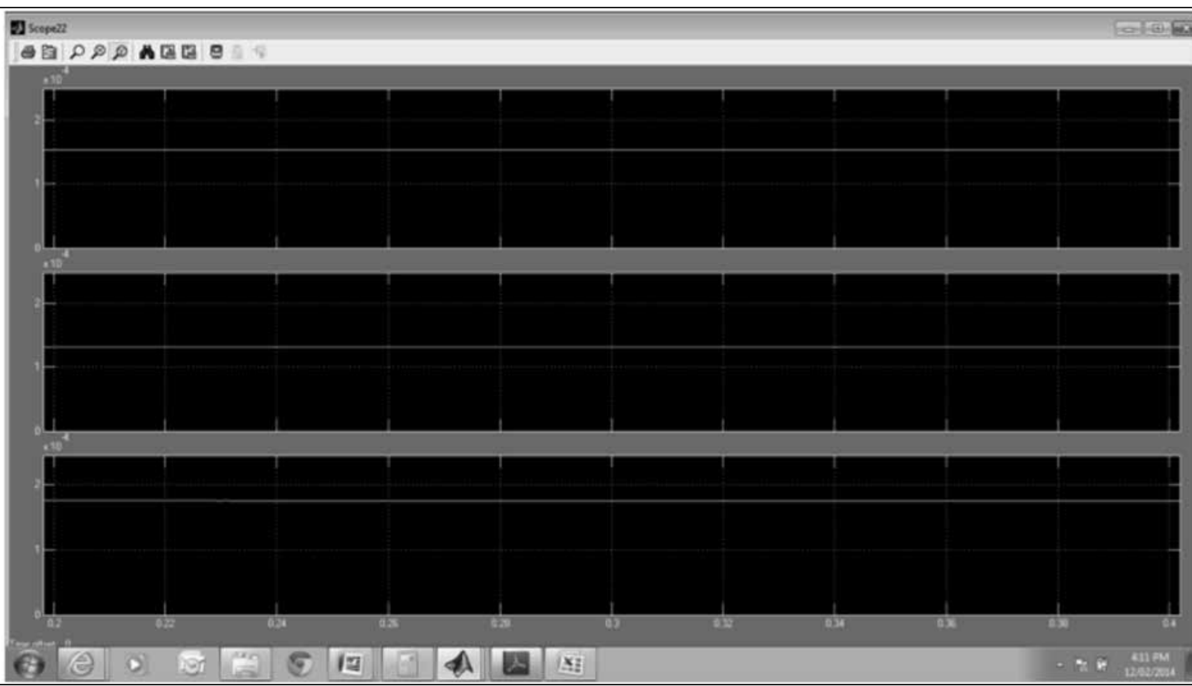
**Load neutral current**

**“With” connecting NCC**



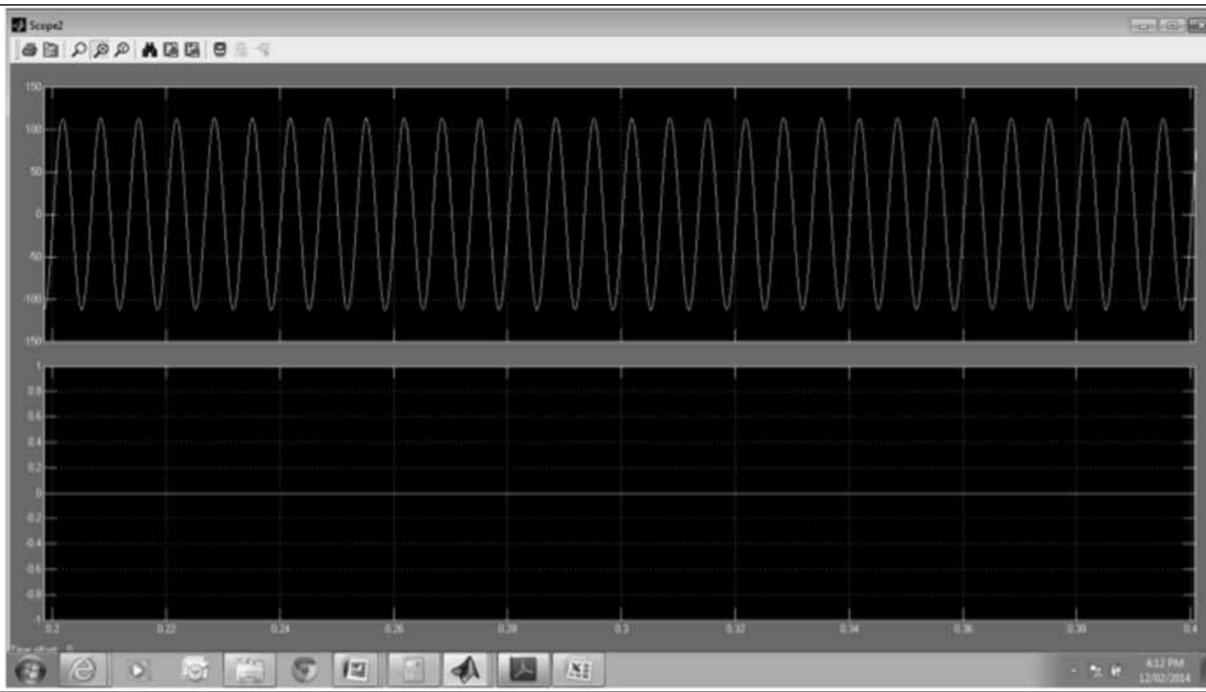
**Ch1, Ch3, Ch5: Phase voltages   Ch2, Ch4, Ch6: Phase currents**

**“With” connecting NCC**



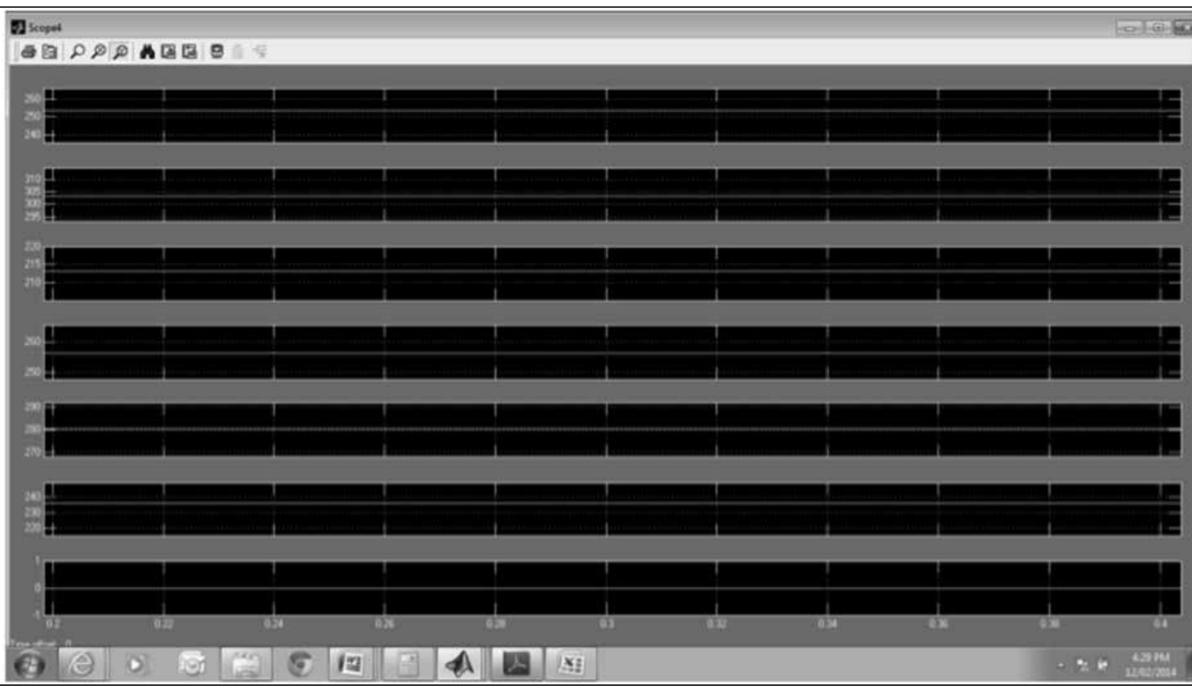
**Ch1, Ch2, Ch3: Phase current distortion (approximately 0%)**

**"With" connecting NCC**



**Ch1: Load neutral current   Ch2: Zero supply neutral current**

**RMS phase voltages "with" and "without" NCC connected**



**Ch1: Vrn without NCC connected (253.4 V)**  **Ch2: Vyn without NCC connected (303.1 V)**

**Ch3: Vbn without NCC connected (213.2 V)**  **Ch4: Vrn with NCC connected (256.3 V)**

**Ch5: Vyn with NCC connected (280.4 V)**  **Ch6: Vbn with NCC connected (236 V)**

**Table -1**

| Parameter | Without connecting NCC | | With connecting NCC | |
|---|---|---|---|---|
| | Average voltage 256.6 V | | Average voltage 257.6 V | |
| | Deviation V | Deviation % | Deviation V | Deviation % |
| $V_{rn}$ | -3.2 | -1.247 | -1.3 | -0.504 |
| $V_{yn}$ | +46.5 | +18.12 | +22.8 | +8.851 |
| $V_{bn}$ | -43.4 | -16.91 | -21.6 | -8.385 |