Impact of Harmonics in Electrical Equipment and Control Systems

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Harmonics

- Linear loads - draw currents that are proportional to applied voltages

  Ex: incandescent lighting heating and motor loads

- Non- linear loads: draw currents only a part of the voltage cycle

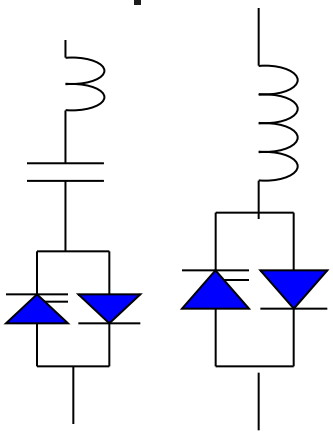
  Ex: Computers, adjustable speed drives and programmable logic converters

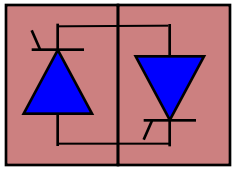
Sources of Harmonics

- Non-linear loads
  - Induction Furnace and Arc Furnace
  - Steel mills and Rolling mills
  - Welding machines
  - Single phase uncompensated railway loads
  - Switching Equipment and Electronic circuits
  - Computers, IT loads
  - UPS, CFL, Fluorescent lights with electronic ballast

Sources of Harmonics

THYRISTOR CONTROLLED DEVICES





- RECTIFIER AND INVERTER STATIONS OF HVDC SCHEME
- THYRISTOR CONTROLLED REACTOR
- THYRISTOR SWITCHED CAPACITOR
- STATIC VAR COMPENSATOR

HARMONICS

Harmonics

- The resulting currents from non-linear loads contains even and odd Harmonics
- Harmonic currents permeate into source currents
- Source currents having harmonic content impact source voltages

Impact of Voltage and current Harmonics

- Amplification of harmonic levels resulting from series and parallel resonances
- Reduction of efficiency on power generation, transmission and Utilization
- Over heating and failure of equipment
- Ageing of insulation of electrical plant
- Maloperation of plant and relays

Impact of Harmonics on rotating machines

- Increased heating due to iron and copper losses at the harmonic frequencies
- Affect machine efficiency and affect torque developed
- Audible noise emission as compared with sinusoidal excitation
- Produce resultant flux distortion in the air gap which can cause cogging or crawling
- Harmonic pairs such as fifth and seventh harmonics have potential for creating mechanical oscillations in a turbine-generator combination or in a motor load system

Impact of Harmonics on Transformers

- Increased audible noise
- Current harmonics cause an increase in copper losses and stray flux losses
- Voltage harmonics cause an increase in iron losses
- Increase in transformer heating (higher order harmonics)
- Upper limit of the current distortion factor is 5% at rated current (IEEE C57.12.0-1987)
- Maximum RMS voltages that the transformer should be able to withstand in steady state 5% at rated load and 10% at no load.

Impact of Harmonics on Capacitors

- A major concern in use of capacitors in a power system is the possibility of system resonance
- The reactance of capacitor bank decreases with frequency and the bank therefore acts as a sink for higher harmonic currents
- This effect increases the heating and dielectric stresses
- Frequent switching of nonlinear magnetic components such as transformers and reactors can produce harmonic currents that will add to the loading of capacitors
- Increased heating and voltage stress by harmonics shortens capacitor life

Impact of Harmonics on Electronic Equipment

- Susceptible to misoperation caused by harmonic distortion
- Equipment is dependent upon accurate determination of voltage zero crossings
- Shifting of the voltage zero crossings or the point at which one phase to phase voltage becomes greater than another phase to phase voltage
- Radio and television equipment as well as in video recorders and audio reproduction systems

Impact of Harmonics on Metering

- Metering and instrumentation are affected by harmonic components particularly if resonant conditions exist that result in high harmonic voltages and currents on the circuits
- Induction disk devices such as watt hour meters, normally see only fundamental current, however phase imbalance caused by harmonic distortion can cause erroneous operation of these devices

Impact of Harmonics on Switchgear and Relying

- Heating and losses in the switchgear there by reducing steady state current carrying capability and shortening the life of some insulating components
- Fuses suffer a derating because of the heat generated by harmonics during normal operation
- Sine wave distortions on power systems and the impact on protective relaying

Harmonics in Power Systems

UTILITY

Increased use of capacitor banks to improve power factor

- Reducing Equipment rating
- Reducing Line losses
- Reducing Voltage drops
- Increasing Voltage regulation

INDUSTRY

Use of Electronic equipment to improve reliability &efficiency

- Variable Speed drives
- Electronic Equipment

Harmonics

Development of solid state Electronics

↓

Delicate appliances --- sensitive to QUALITY OF POWER

Distortion of the waveform

↓

HARMONICS

Harmonic Distortions

- Total Harmonic Distortion(THD)

$$\frac{\sqrt{\sum I_i^2}}{\sum I_1} \quad for \quad i = 2 to \infty \quad THD = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_1}$$

- These do not include aperiodic signals such as noise, inter-harmonics, sub-harmonics, chaotic signals other non-characteristic harmonics, dc components etc.
- When harmonics travel upstream, a certain amount of cancellation takes place and measured at PCC

Harmonic Distortions

- Ratio of RMS value of total harmonic content to RMS value of fundamental
- The THD is zero for a perfectly sinusoidal wave. It increases indefinitely as the wave form distortion increases
- A THD of 5% is commonly cited as the border line between high and low distortion for distribution circuits
- Balanced THD includes only positive and negative sequential signals and Residual THD includes only triplen or zero sequence signals

CUSTOM POWER DEVICES

Power electronic controllers coming to use on distribution systems will enable utilities to provide premium quality of power to consumers called the custom power devices

SOLID STATE TRANSFER SWITCH

SOLID STATE BREAKER

DISTRIBUTION STATIC COMPENSATOR

DYNAMIC VOLTAGE RESTORER

Measures to improve Power Quality

- Networks with less than 20% of harmonic loads use power capacitors
  - Improve Pf
  - Reduce voltage dip and flicker
- Networks with more than 20% of harmonic loads use Fixed detuned filters and Active harmonic filter

Voltage distortion limits as per IEEE 519-1992:

Voltage distortion limits		
Bus Voltage at PCC	Individual voltage Distortion (%)	Total voltage distortion THD (%)
<69 kV	3.0	5.0
69 kV to 161 kV	1.5	2.5
>161 kV	1.0	1.5

Current distortion limits as per IEEE 519-1992:

Maximum current distortion in percent(%) of IL (120V through 69000V)						
Individual harmonic order(odd harmonics)						
Isc/IL	<11	11≤ h <17	17≤ h <23	23≤ h <35	35≤ h	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.0	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of odd harmonics						

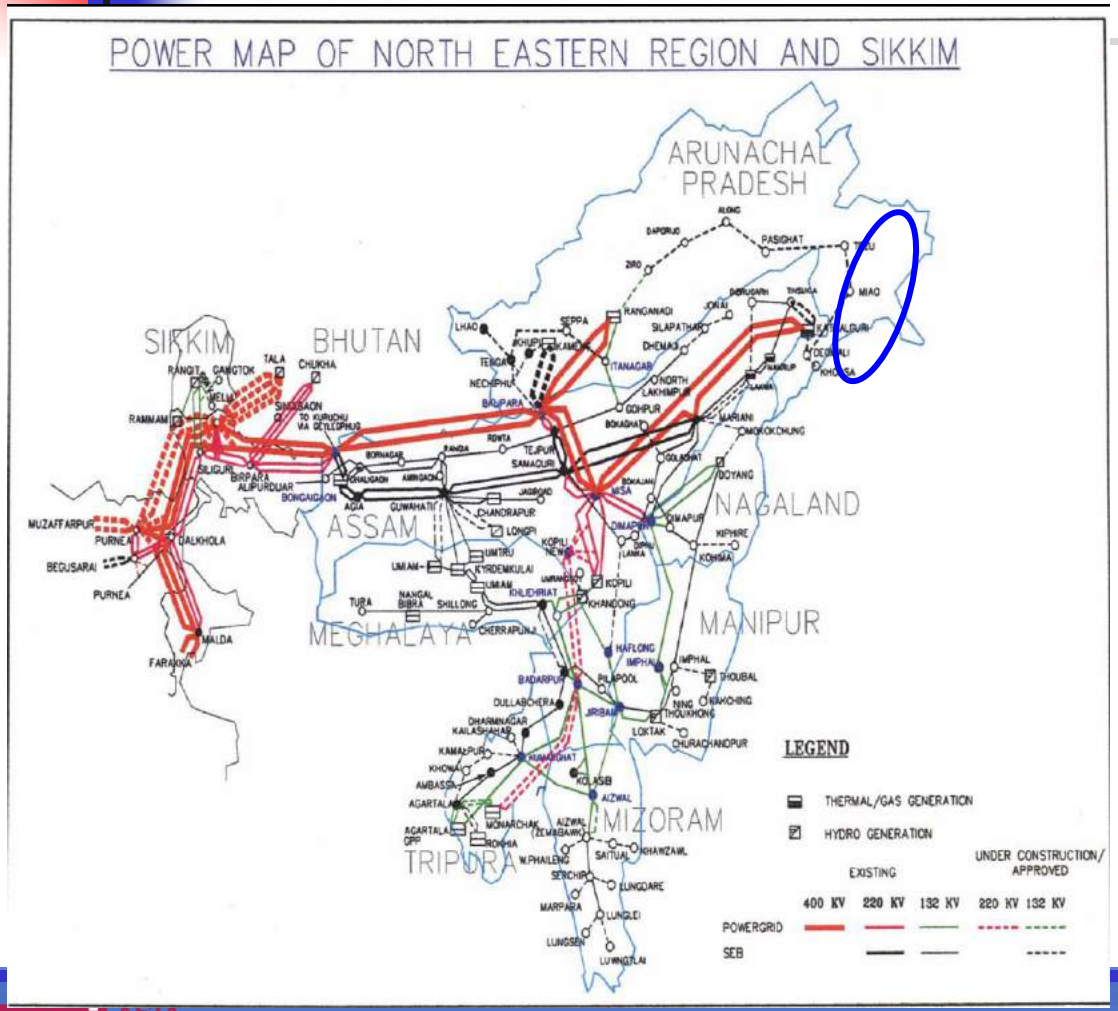
Current distortion limits as per IEEE 519-1992:

Maximum current distortion in percent(%) of IL (69001 through 161000V)						
Individual harmonic order(odd harmonics)						
Isc/IL	<11	11≤ h <17	17≤ h <23	23≤ h <35	35≤ h	TDD
<20*	2.0	1.0	0.75	0.3	0.15	2.5
20-50	3.5	1.75	1.25	0.5	0.25	4.0
50-100	5.0	2.25	2.0	0.75	0.35	6.0
100-1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0
Even harmonics are limited to 25% of odd harmonics						

HARMONIC MEASUREMENT STUDIES & FILTER DESIGN STUDIES

- Usha Martin Industries, Jamshedpur
- Usha Beltron Industries, Ranchi
- Tata Iron & Steel Company, Jamshedpur
- HVDC System, Rihand
- ISPAT, Bombay
- ER&DC, Tiruvanathapuram
- POWERGRID NE Region

Harmonic Measurements in POWERGRID NE Region



- CPRI has carried out harmonic measurements at 132 kV and 33 kV Nirjuli substation of NER grid

- Design of Filters for suppression of harmonics at Nirjuli sub station.

Harmonic Measurements in POWERGRID NE Region

- Measurements carried out for 9 days
- Power analyzer "PowerPro" instrument is used simultaneously at different locations (Candura make)
- Measurements are carried out at different load points and during different generating conditions

Harmonic Measurements in POWERGRID NE Region

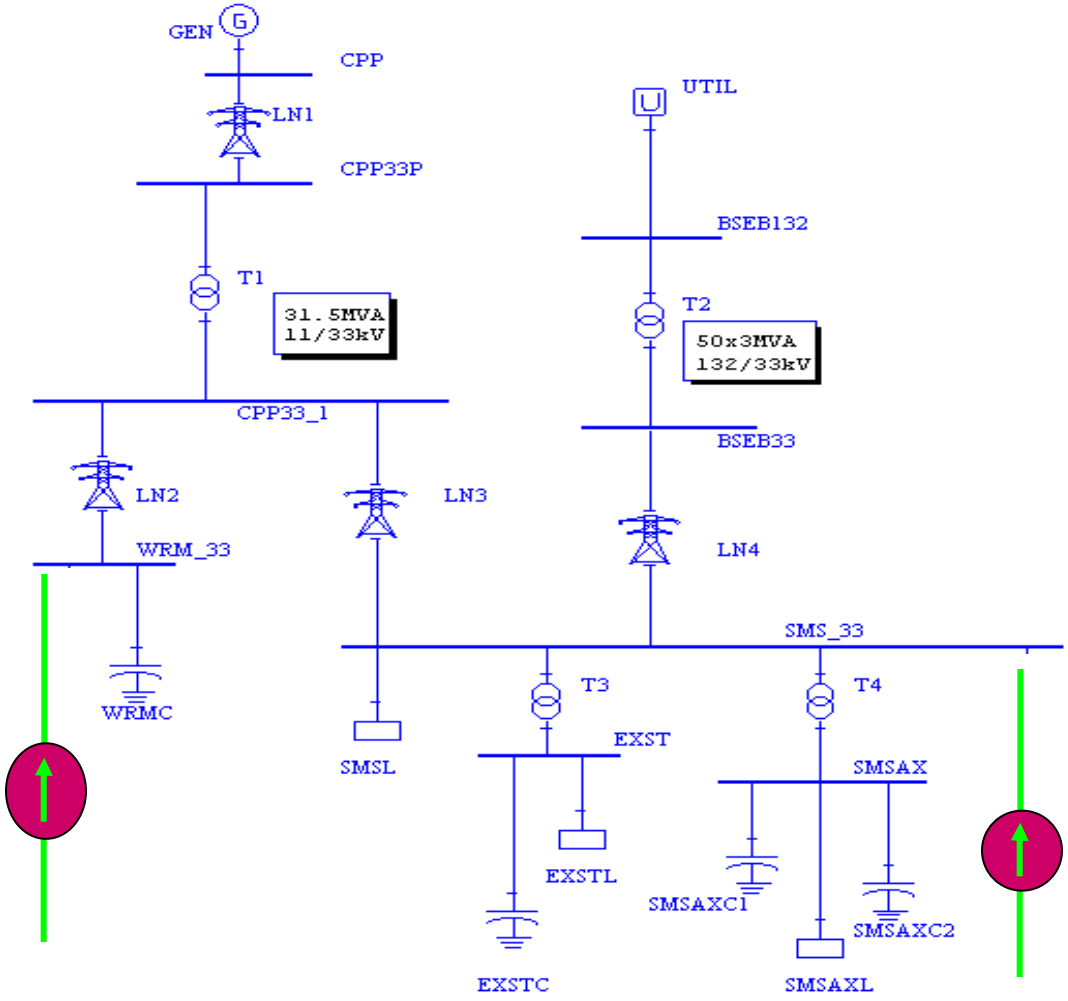
- Investigated using this analyzer
  - Trends in Voltage, Current, Power and Frequency
  - Waveforms and harmonic activity for both voltage and current
  - Voltage sags and swells
  - Frequency deviations
- The desired parameters can be viewed on the logger front panel and/ or analyzed using Power View software after transferring the data to the computer

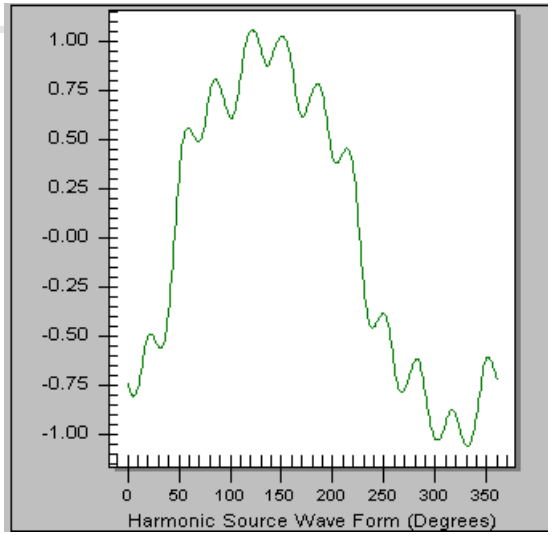
Harmonic Measurements in POWERGRID NE Region

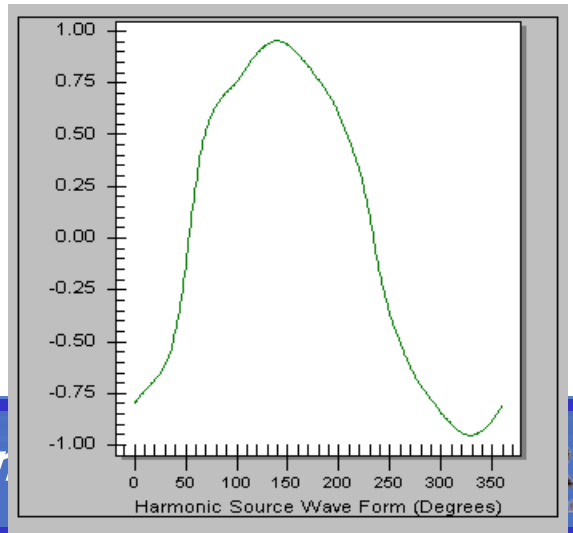
- The PowerPro is an 8-channel power quality data logger.
- It acquires 3 phase voltages and currents, at the Sampling rate of 256 Samples per cycle.
- Parameters like RMS values, Real power, Apparent power, power factor and reactive power are updated every half cycle and the average, minimum & maximum of these quantities are stored at specified storage intervals.

Filter Design Studies for

14MVA ELECRTIC ARC FURNACE

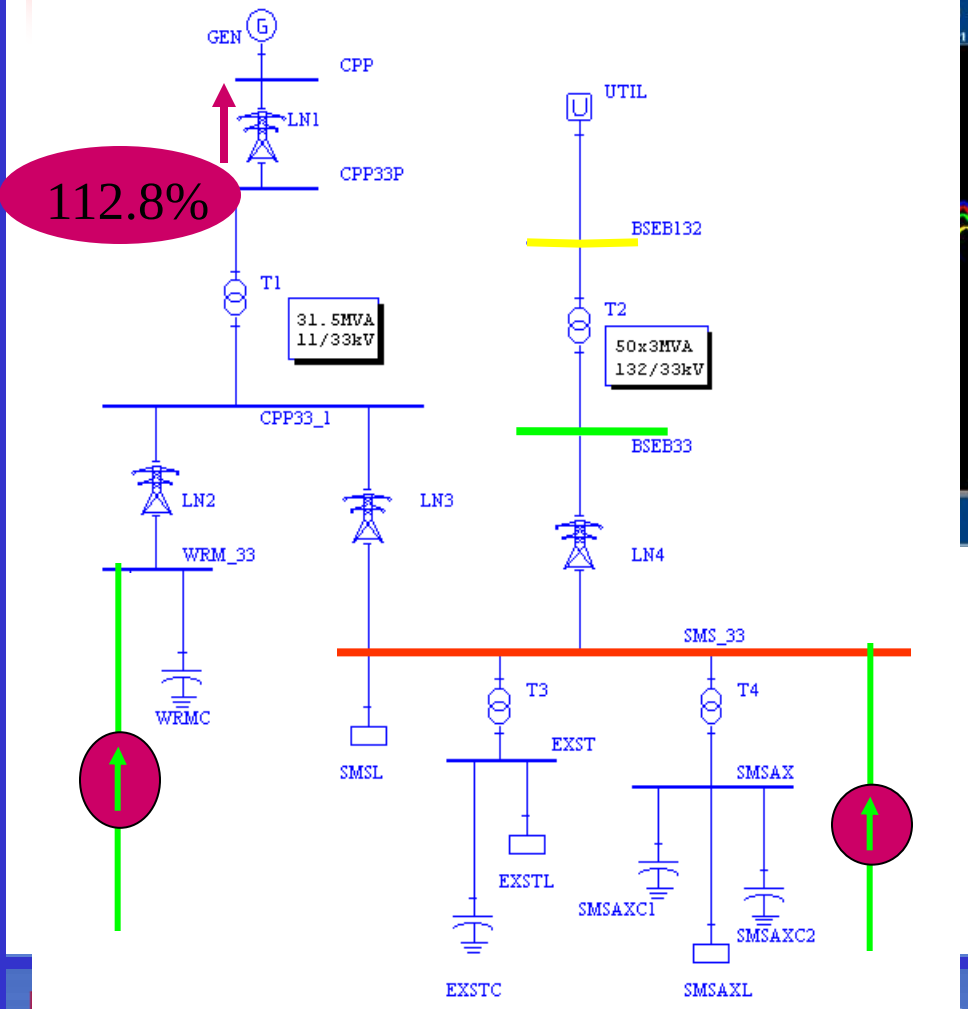


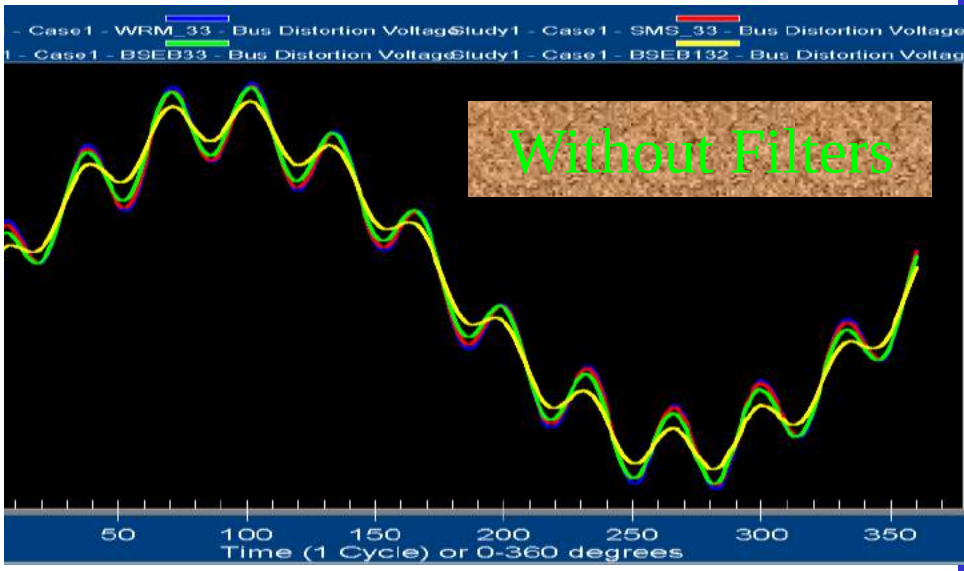




Filter Design Studies for

14MVA ELECRTIC ARC FURNACE

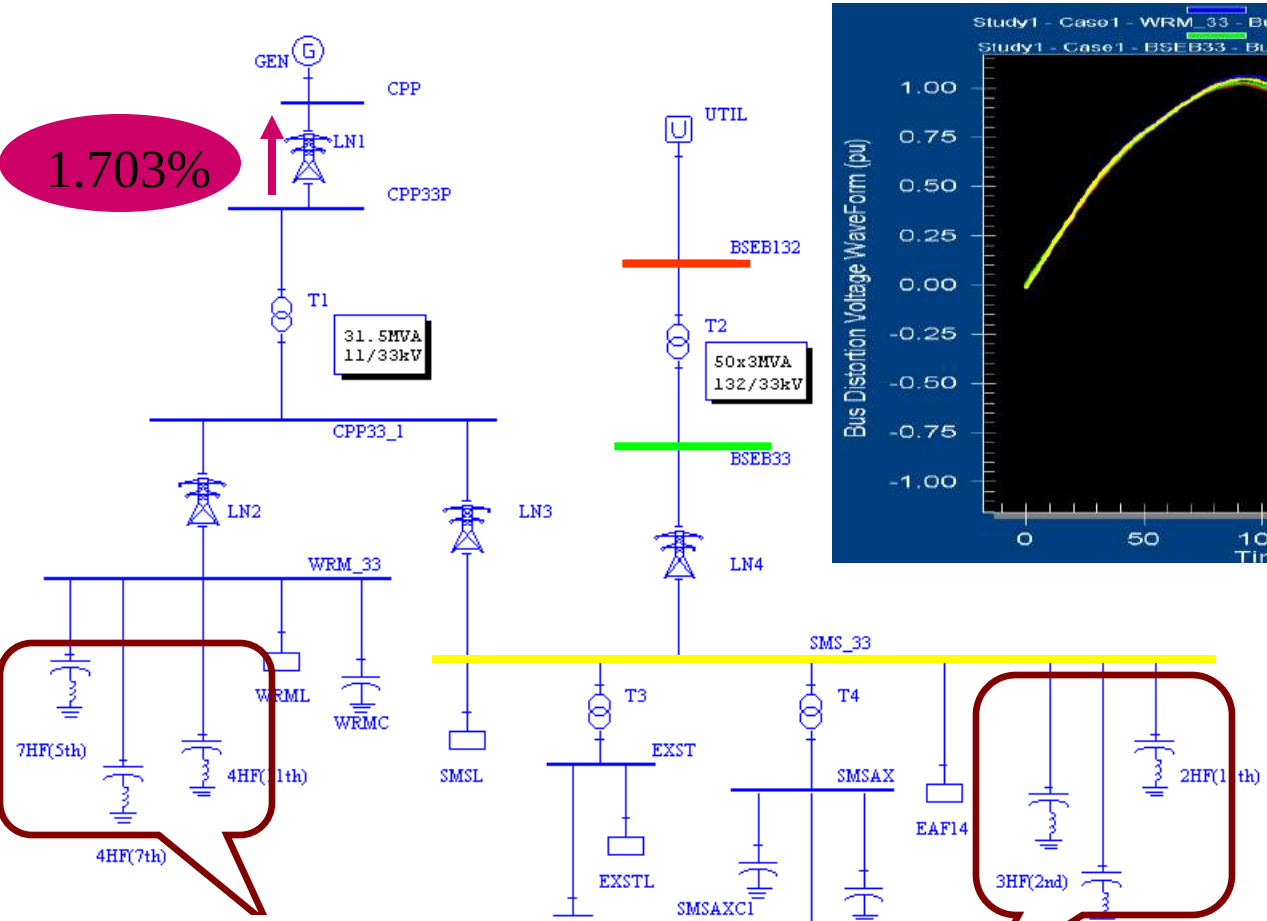


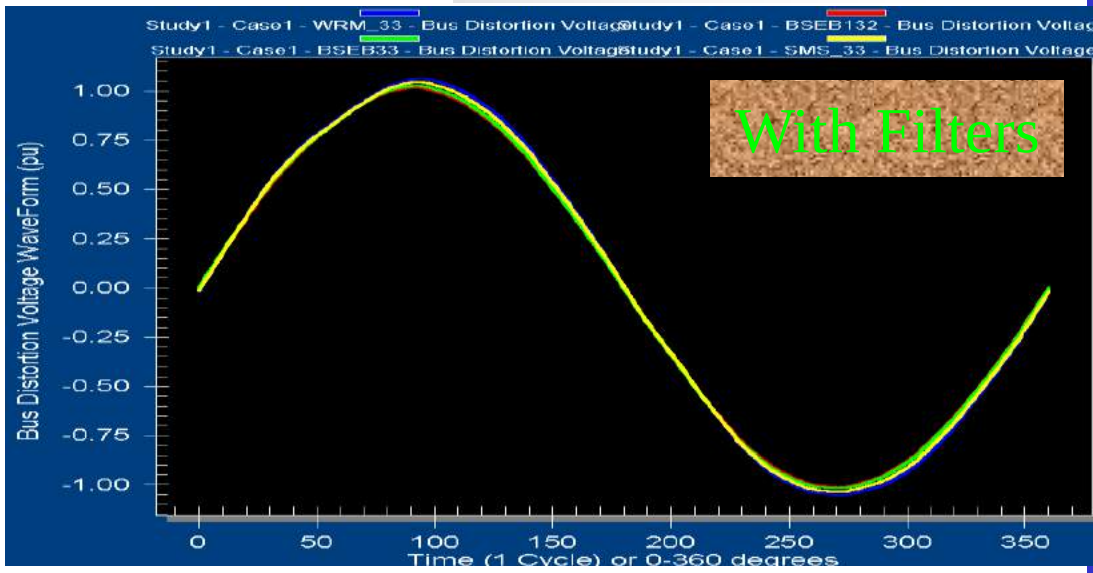


BUS_NAME	V_THD
BSEB	11.008
BSEB33	18.601
SMS	18.621
WRM	18.636
CPP33_1	18.628
CPP	11.208

Filter Design Studies for

14MVA ELECRTIC ARC FURNACE





BUS_NAME	V_THD
BSEB	0.903
BSEB33	1.509
SMS	1.511
WRM	1.512
CPP33_1	1.512
CPP	0.748


THANK YOU