International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-2, Issue-4, July 2015

Harmonics, its Mitigation & Result of Case study of Spinning Mill

Yogesh Subhash Shimpi
M. Tech Electrical,
Bharati Vidyapeeth Deemed University,
Pune, India.

Prof. D. S. Bankar
Ph. D. Electrical,
Bharati Vidyapeeth Deemed University,
Pune, India.

ABSTRACT
Harmonics plays very important role in the stability and economic operation of the power system. Harmonics results in heating of equipments and under efficiency of the electrical components. In this report we have tried to throw light on the location & selection of the filter to be used in the power system. The case study of the spinning mill was to carry out the study of the harmonics levels as against the IEC standards and reduce overall losses of the system by maintaining the noise level within acceptable limits. The voltage and current distortion levels were also analysed.
The report is made in order to present the details of harmonics and how can they be neutralised. Furthermore the optimum method using active harmonics filters is discussed along with some frequently asked queries and standards.

Keywords
Harmonics, Integer Harmonics, Sags, Active Filters, Passive Filters, Harmonics Standards.

1. INTRODUCTION TO HARMONICS
Harmonics are multiples of the fundamental frequency currents, generated due to 'non-linear' loads. Say supply with frequency of 50 hertz, 250 hertz and 350 hertz will be fifth and seventh harmonics generated. These are called 'integer harmonics' - i.e. exact multiples of the supply frequency. The AC to DC power conversion equipments circuits draws short pulses of current from the supply network and their interaction with the source impedance results in distortion of the supply voltage.

2. HARMONICS EFFECTS
The effects of voltage and current harmonics on power system are:-

1. Amplified harmonics levels resulting from series and parallel resonance;
2. Efficiency reduction of power generation, transmission, and utilization;
3. Early wear and tear of the equipments of the plant components;
4. Plant malfunction;
5. Malfunctioning and failure of electronic equipment;
6. Motors failure due to heating;
7. Overloading, overheating and failure of power factor correction capacitors. Resonance due to interaction of capacitors with harmonics;
8. Transformer heating and loading of neutrals
9. Metering errors;
10. Nuisance tripping of switchgear
11. Voltage glitches in computers systems resulting in lost data. Excessive flicker on VDU's;
12. EMI with Television, frequency communication and signalling
13. Automatic voltage regulators damaging to diesel generators sets.
14. Rippling current system Interference

3. HARMONICS SOURCES
The main sources of voltage and current harmonics within the power system are:-

A. Single-Phase

1. Computers, fax machines, Xerox machines, Uninterrupted power supply units, Television sets,
2. Dimming rheostats & ballasts for lighting;
3. Drives
4. UV disinfectant systems;

B. Three- Phase

1. Variable speed and frequency drives;
2. Uninterrupted power supply systems;
3. Furnaces & Silicon Control Rectifier controllers:
4. Battery chargers;

In fact any single or three phase electrical power conversion equipment which converts from AC to DC.

4. METHODS OF HARMONICS MITIGATION
Methods of harmonics mitigation include:-

A. Phase Shifting;
B. Passive Filters;
C. Phase Staggering;
D. Active Filters.

A. Phase Shifting

The commonly used is phase shift transformer which creates two supplies displaced in phase by 30º from the original supply. By feeding two 6-pulse diode rectifiers to create a 12-pulse rectifier, certain harmonics will be opposite in phase and magnitude, and will cancel out each other.
Solutions up to quasi 48-pulse can be created.

B. Passive Filters

Passive filters are series capacitor & reactor resonant circuits ‘tuned’ to present a low impedance path to a specific frequency (i.e. 5th - 250Hz, 7th - 350Hz).
They are mostly connected to Power Control Centre to prevent harmonics ‘feeding' into the utility power supply". However they can also be connected to end loads in the consumer premises.

Because of the harmonics generation and noise production, there is necessity of the study of the component present of the level of harmonics in the power system. There may be a problem of If multiple filters are installed anti-resonance is a problem. It has to be installed with caution.

Typical total harmonics distortion to be limited to ~ 10-15%

C. Phase Staggering

Phase staggering is just the phase shifting of individual loads such that the harmonics produced by one or more loads cancels the harmonics produced by others.
For successful phase staggering at least two balanced loads of similar ratings are required.

D. Active Filters

They are very modern and economic solution in reduction of current waveform distortion up to 5 per cent in line with Institute Of Electrical and Electronics Engineers 519-1992.
This hybrid filter is monitoring I_{THD} needed at the load.

Near the connecting points current which is generated by the hybrid filter is put into supply at load end.

Compensation is provided from second to fifty first harmonics.

5. ACTIVE HARMONICS FILTERS

The proven technology for isolating current due to harmonics voltage and current is Active Harmonics Filter (AHF). It protects damage to equipment because of current and voltage distortion. These filters are very advanced provides effective solution for reduction of current distortion. As per Institute Of Electrical and Electronic Engineers standard 519 its value should not be more than 5%.

The following actions are taken by filter:-

1. Harmonics suppression;
2. Control in Reactive current;
3. Suppression on Load side transient;
4. Suppression on Load side surges;
5. Reduction in the supply sags and surges effects (flickering).

A. Working of the Active Filter:-

It monitors harmonics currents at load end and waveform is generated to match the non linear shaped portion of the consumer load current.
At the point of connection the adaptive current injection generated by filter into the load is done. Thus fundamental frequency current is fed to load by supply end.

From the second to the 51st harmonics compensation is done in short span of time of 100 micro-seconds or lesser.

B. Feature and benefits of active harmonics filter

1. The range of filter is from 25A to 400A. In paralleled cases 1000A is also suitable arrangement. The voltage range is 208V to 600V.
2. Useful for 3 phase, 4 wire distribution networks where unbalanced loads tend to create disturbance.
3. Can be assembled in panel form or comes as standalone unit.
4. No programming is required as it can be accustomed to worldwide needs.
5. It's connections are very easy. Very less inventory of only two numbers of current transformers are to be kept.
6. System impedance does not produce any effect on it.
7. It can correct harmonics at load, source or feeder end.

6. SPECIFICATIONS

A. Technical Specifications

1. Input Supply
2. Supply Voltage
3. 208Volts to 600V
4. Supply Frequency
5. 50 Hz or 60 Hz, nominal variation ± 5%
6. Number of Phases
7. 3 phase, 3 wire or 3 phase 4 wire
8. Current Transformers

B. Technical Specifications

1. Harmonics Current : Orders of 2^{nd} to 51^{st} harmonics compensation
2. Time for Initialisation : 6 seconds maximum
3. Response Time : up to 100 micro-seconds
4. Current Limiting : 100% rating, irrespective of value of harmonics current
5. Peak value of Harmonics current : 3 times peak instantaneous
6. Interrupting Capacity : Up to 200 kA
7. MTBF : 10 years
8. PFC Improvement : Yes
9. Transient current suppression : Yes
10. Rapid Load Variation : Yes
11. Parallel Configuration : Yes

C. Interface at User end

1. C & I Panel
2. Switch Indicators
   - On-Off / Reset
   - Power
   - Operation mode
   - Fault warning
   - Temperature Warning

D. Environmental Conditions

1. Operating Temperature : 0 to 42°C
2. Storage Temperature : -31°C to +64°C
3. Rh value : ≤95%, zero condensation
4. Altitude levels : till 1500 m

E. Harmonics Standards

1. Harmonics Limits : IEEE 519 (1992)
2. General Guide on Harmonics, Inter harmonics Measurements and Instrumentation : EN 1000-427 (1994), IEC1000-3-4

F. Reference Standards

1. European Union requirements for Power Assemblies : EN 50178
2. European Union requirements for Low Voltage Assemblies : EN 60439

3. Vibration Standard : ICBO Building Code, Section 16, Seismic Zone 4
4. Surge Withstand Capability : IEC 61643-1, UL 1449-2, without damage
5. Transient : IEEE 587 Class B
6. Protection: IP20 rated enclosure (standard) Other ingress of protection on request

G. Electromagnetic Compatibility (EMC)

1. Conducted and Radiated Emission : EN 55011
2. Electrostatic Discharge : IEC61000-4-2
3. Radiated Immunity : IEC61000-4-3
4. Electrical Past Transient : IEC61000-4-4
5. Surge : IEC61000-4-5
6. Power Frequency Field Immunity Tests : IEC61000-4-8
7. Pulse Magneting Field Immunity Tests : IEC61000-4-9
8. Damped oscillatory Field Immunity Tests : IEC61000-4-10
9. Approvals : IEC, BS, UL, cUL, CSA

7. ROOT CAUSES OF THE NEED TO STUDY

A. Hazards due to Harmonics:-

1. Harmonics levels Amplification due to parallel and series resonance
2. Inefficiency of generation, transmission, and distribution
3. Aging of the installation components
4. Mal-operation of plant
5. Electronic equipment Malfunctioning and its failure
6. Overheating and failure of electric motors
7. PFC overloading, overheating and failure. Noise due to capacitor and harmonics action
8. Neutral conductor heating of transformers
9. Metering errors
10. Nuisance tripping of switchgears
11. Data loss due to Voltage surges in computers
12. EMI with TV, radio, communication & telephone systems
13. Damage and disruption to emergency diesel generators and associated automatic voltage regulators control equipment

B. Regulations to control Harmonics level:-

As per IEEE Recommendation the levels of harmonics distortion in system with non-linear loads should not be more than 5%.

The emission regulations observed in the Recommendation are:

Harmonics, sub-harmonics & inter-harmonics voltage distortion level within the range of 0 to 2500Hz

Small time surge of V_{THD}

Institute of Electrical Engineers recommends the standard IEEE 519-1992, which defines the maximum recommended voltage distortion (VTHD) for 'general systems' to be less 5%, with no more than 3% of any individual harmonics. This is to prevent out of service of the power sensitive equipment. As per IEEE 519-1992 I_{THD} as under 5 classes of 5%, 8%, 12%, 15% and 20%.

C. Harmonics Distortion Measurement:-

The process of calculating the magnitude and phases of the fundamental and higher order harmonics of the periodic waveform.

We have to recommend the True rms instruments which will give us all the information that can be used to minimize harmonics levels.

D. Problem arising due to Harmonics:-

Equipment like UPS, variable speed drives or variable frequency drives, battery chargers, etc. then harmonics is bound to be generated in the system. The following are the signs that there is harmonics problem;

i) premature failing of electric motors and transformers, ii) overheating of cables, iii) nuisance tripping of switchgears, iv) data loss. Measurements shall be taken at various locations like load, source and feeder end to analyse the extent of the problem. These can be taken using True RMS instruments or by a specialist for site visit.

E. Overlooking Problem:-

If not addressed properly, problem can lead to unnecessary and costly disruptions in power system stability. It may even cause a fire as well. Issue address may sound expensive sometimes but Addressing the problem can sometimes be expensive, but it ends up the smartest and economical option in the end.

8. RESULTS OF CASE STUDY

PARAMETERS	REFERENCE LIMITS	REFERENCE STANDARD	Recorded Value	Result
Feeder Name	**Blow Room Capacitor ON**			
Power Frequency	Mean value of fundamental measured over 10 s: +/- 2% for 99.5% of week;	EN 50160	0.78%	Passed
Rapid voltage changes	3% normal, 4% maximum, P_{st}< 1, P_{lt}< 0.65	EN 61000-2-12	Pst – 2.840	Failed
Voltage Swells / dips	LV: 10-50%; Locally limited swells / dips caused by load switching: swell/dip up to 30% of V-RMS and duration up to 10ms;	EN 50160 EN 61000-6-1-2	Not observed during the study	Passed
Short interruption of supply	95% reduction for 5seconds;	EN 61000-6-1	Not observed during	Passed

PARAMETERS	REFERENCE LIMITS	REFERENCE STANDARD	Recorded Value	Result
voltage		& 6-2	the study	
Long interruption of supply voltage	LV-MV: (up to 3 minutes) <10-50/year, EN 50160.	EN 50160	Not observed during the study	Passed
Transient over-voltage	+/- 2KV (Line to Earth), +/- 1KV (Line to Line), 1.2KV/50KA(8/20us) Tr/TH us;	EN 61000-6-1 & 6-2	Not observed during the study	Passed
Supply voltage unbalance	Positive, negative and zero sequence; 2% between Line to Line;	EN 61000-2-12	0.80%	Passed
Load unbalance	Positive, negative and Zero sequence, leakage currents <500Ma	EN 50160	7.2%	Passed
Harmonics voltage	V-THD<5%, Individual V-h <3%;	IEEE 519	12.30%	Failed
Harmonics current	I-THD %: as defined by ratio of I(short circuit)/I(full load); TDD – **15%**	IEEE 519	18.40%	Failed

Harmonics Distortion Summary:

SUMMARY OF HARMONICS OBSERVATIONS

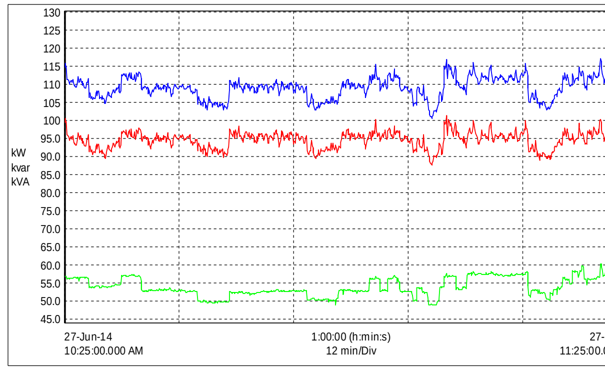
Terms	Values	Unit description
V_{LL}	433	V, 3ph.
KVA (Souce)	1600	KVA
Amps (source)	2133.46	Ampere (source)
Cricuit Breaker Amps	400.00	A (feeder)
U_{CC}% (source)	6.25%	%Z (source)
U_{CC}% (feeder)	1.17%	%Z (feeder)
U_{CC}% (line)	0.20%	%Z (line)
X_{CC}(feeder)	25.7199	Ohms (impedance in ohms)
ShortCkt A (feeder)	29124.97	I_{SC} (HT) As per BS7430
I_{SC} / $I_{L\ (rated)}$	194.17	Ratio of Transformer short ckt amps to measured max
%V(TDD)	<5%	As per IEEE519, 1992
%I(TDD)	<15%	

Measured Harmonics - THD(%)

I(load)	150.00	Amps	Load current
I_{SC} / $I_{L\ (load)}$	194.17	Ratio	Short ckt amps / measured load
THD-I (%)	18.40%	I-THD	Above limit
THD-V (%)	12.30%	V-THD	Above limit

Power Parameters:
Active Power (KW), Apparent Power (KVA), Reactive Power (KVAR):

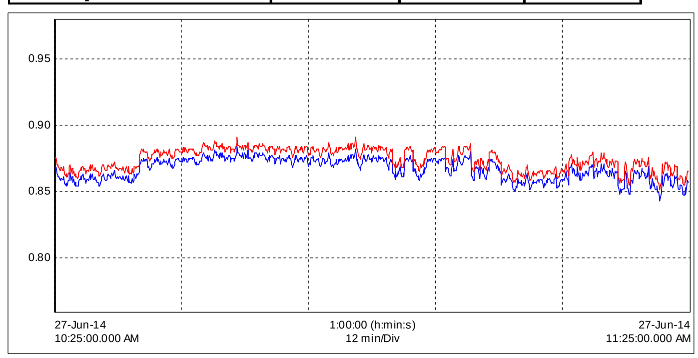
Parameters	Avg.	Min.	Max.
Active Power (KW)	94.606	87.64	101.48
Apparent Power (KVA)	109.25	100.62	118.48
Reactive Power (KVAR)	54.03	48.78	61.23



Active Power (KW) ---------, Reactive Power (KVAR)---------, Apparent Power (KVA) -----

Power Factor:

Parameters	Avg.	Min.	Max.
True Power Factor	0.867	0.843	0.884
Displacement PF	0.874	0.850	0.891



Active Power (KW) ----------, Apparent Power (KVA) -----

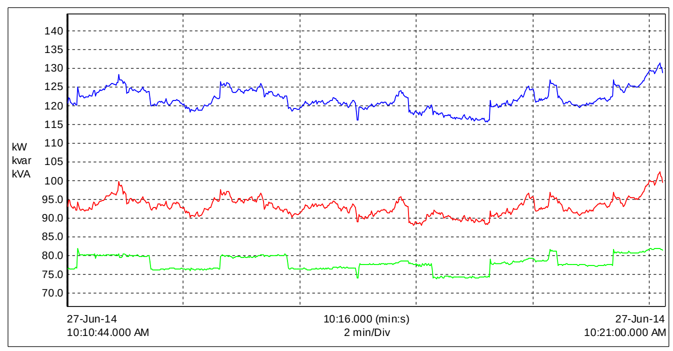
PARAMETERS	REFERENCE LIMITS	REFERENCE STANDARD	Recorded Value	Result
Feeder Name	**Blow Room Capacitor OFF**			
Power Frequency	Mean value of fundamental measured over 10 s: +/- 2% for 99.5% of week;	EN 50160	.84%	Passed
Rapid voltage	3% normal, 4% maximum, P_{st}< 1,	EN 61000-2-	Pst – 10.180	Failed

PARAMETERS	REFERENCE LIMITS	REFERENCE STANDARD	Recorded Value	Result
changes	P_{lt}< 0.65	12		
Voltage Swells / dips	LV: 10-50%; Locally limited swells / dips caused by load switching: swell/dip up to 30% of V-RMS and duration up to 10ms;	EN 50160 EN 61000-6-1-2	Not observed during the study	Passed
Short interruption of supply voltage	95% reduction for 5seconds;	EN 61000-6-1 & 6-2	Not observed during the study	Passed
Long interruption of supply voltage	LV-MV: (up to 3 minutes) <10-50/year, EN 50160.	EN 50160	Not observed during the study	Passed
Transient over-voltage	+/- 2KV (Line to Earth), +/- 1KV (Line to Line), 1.2KV/50KA(8/20us) Tr/TH us;	EN 61000-6-1 & 6-2	Not observed during the study	Passed
Supply voltage unbalance	Positive, negative and zero sequence; 2% between Line to Line;	EN 61000-2-12	0.80%	Passed
Load unbalance	Positive, negative and Zero sequence, leakage currents <500Ma	EN 50160	6.3%	Passed
Harmonics voltage	V-THD<5%, Individual V-h <3%;	IEEE 519	12.50%	Failed
Harmonics current	I-THD %: as defined by ratio of I(short circuit)/I(full load); TDD – **15%**	IEEE 519	16.7%	Failed

SUMMARY OF HARMONICS OBSERVATIONS			
Terms	Values	Unit description	
V_{LL}	433	V, 3ph.	
KVA (Souce)	1600	KVA	
Amps (source)	2133.46	Ampere (source)	
Cricuit Breaker Amps	400.00	A (feeder)	
U_{CC}% (source)	6.50%	%Z (source)	
U_{CC}% (feeder)	1.22%	%Z (feeder)	
U_{CC}% (line)	0.20%	%Z (line)	
X_{CC}(feeder)	26.5987	Ohms (impedance in ohms)	
ShortCkt A (feeder)	28162.70	I_{SC} (HT) As per BS7430	
I_{SC} / $I_{L\ (rated)}$	160.93	Ratio of Transformer short ckt amps to measured max	
%V(TDD)	<5%	As per IEEE519, 1992	
%I(TDD)	<15%		
Measured Harmonics - THD(%)			
I(load)	175.00	Amps	Load current
I_{SC} / $I_{L\ (load)}$	160.93	Ratio	Short ckt amps / measured load
THD-I (%)	16.70%	I-THD	Above limit
THD-V (%)	12.50%	V-THD	Above limit

Active Power (KW), Apparent Power (KVA), Reactive Power (KVAR):

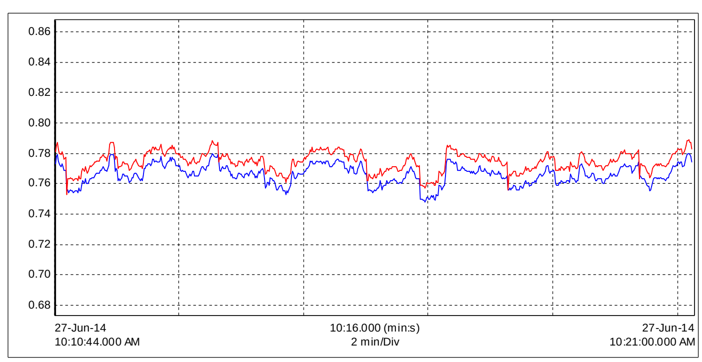
Parameters	Avg.	Min.	Max.
Active Power (KW)	93.124	88.04	102.31
Apparent Power (KVA)	121.27	154.80	173.38
Reactive Power (KVAR)	78.02	73.85	82.02



Active Power (KW) ----------, Reactive Power (KVAR)----------, Apparent Power (KVA) ----------

Power Factor:

Parameters	Avg.	Min.	Max.
True Power Factor	0.766	0.748	0.780
Displacement PF	0.774	0.753	0.789



9. CONCLUSION

The above results were obtained while doing the power system analysis after capacitor ON and the result shows that the voltage and current THD levels are above permissible limits. The report was submitted to technical committee of the spinning mill. The decision was taken to install the filters to avoid further damage to system and improve system stability.

REFERENCES

[1] IEC 519 1992 – Harmonics Limits

[2] EN 1000-427 (1994), IEC1000-3-4 - General Guide on Harmonics, Inter harmonics Measurements and Instrumentation

[3]EN 50178 - European Union requirements for Power Assemblies

Yogesh Subhash Shimpi, M.Tech Student in Electrical Power Systems, Bharati Vidyapeeth Deemed University College of Engineering Pune

Prof. D. S .Bankar, Ph.D. candidate at Bharati Vidyapeeth University,Currently working as Associate Professor in Electrical Engineering Department of Bharati Vidyapeeth University College of Engineering Pune, India