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Power Quality Improvement, Harmonic Elimination and Load Balancing in Industrial Power System

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ABSTRACT

Non-linear loads are increasingly more abundant in commercial, residential and industrial sector and their percentage of the total load are growing steadily. The increasing uses of non-linear loads are becoming more harmonic problems at utilities and customers sides. The harmonic problems cause damage of system equipment and low power quality. The most appropriate solution to mitigate this issue is passive filter. Passive filters are typically composed by inductors, capacitors and resistors which are used for mitigating harmonic distortions, power factor correction and improving power quality. In this paper, simulation models are implemented for mitigating harmonic distortions by applying passive filter at No (3).Steel Mill (Ywama, Yangon) in distribution system. Passive filters are installing at point of common coupling (PCC) of 11kV feeder in distribution system to reduce the harmonic distortion within IEEE 519-1992 standards. THD is used as the harmonic index to study the effect of harmonic distortions. In this paper, the performance of the designed filter in this network and THD are obtained from simulation using MATLAB.

KEYWORDS: *Total Harmonic Distortion (THD), Non-Linear Loads, Passive Filter, Point of Common Coupling (PCC)*

1. INTRODUCTION

In modern electric power supply distribution system, there is a sharp rise in the use of single-phase and three-phase non-linear loads.

These non-linear loads generation have solid state control of electric power and draw non-sinusoidal unbalance current from ac mains resulting in harmonic injection, reactive power burden, excessive neutral current and unbalanced loading of ac mains. Now a day's power quality in electrical energy system has become a major challenge for engineers to maintain the sinusoidal waveform in the system if there is any distortion come in the waveform is known as Harmonic in the system.

Harmonic is a problem arises due to use of Non-linear load or in other word we can say that from solid state component. Harmonics are the major source of sine waveform distortion and the increased use of nonlinear equipment has caused harmonics to become more common. Harmonics are integer multiples of the fundamental frequency of the sine wave or 60 Hz (50 Hz for Myanmar) fundamental voltage and current. They can be 2, 3, 4, 5, 6, 7, etc., times the fundamental and they add to the fundamental 50 Hz waveform and distort it.

For example, third harmonic is 3 times of 50 Hz or 150 Hz, and eleventh harmonic is 11 times of 50 Hz, 550 Hz. Harmonic currents and voltages have a detrimental effect on utility and end-user equipment.

Nonlinear loads cause harmonic currents to change from a sinusoidal currents to a non-sinusoidal current by drawing short bursts of current each cycle or interrupting the current during a cycle. Harmonic mitigation techniques provide several benefits: improved system performance, increased equipment lifetime and financial savings. Passive filter is a well-known technology to solve this issue. Passive filters are widely used in industrial power systems to limit harmonics' undesired affects.

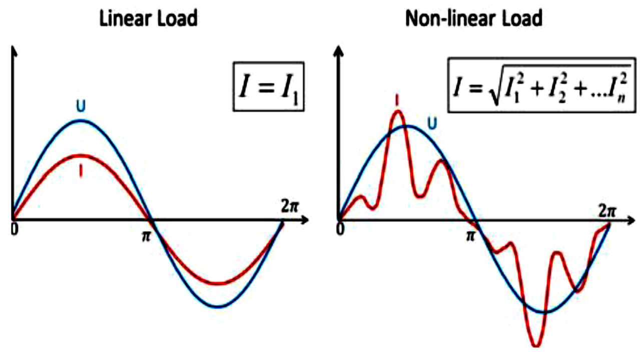

Fig.1 Sinusoidal Waveform and Non-sinusoidal Waveforms

2. HARMONIC MITIGATION SOLUTIONS

Harmonic filtering can improve equipment performance and reduce energy costs by eliminating unwanted harmonics in electrical systems created by non-linear loads. Harmonics are the drawback of power quality in power system. There are several basic methods for reducing harmonic voltage and current distortion from nonlinear distribution loads. Filter is a method to reduce harmonics when the harmonic distortion has been increased in industrial plants. Harmonic filter minimize the thermal and electrical stress on the electrical infrastructure. It can improve phase current, voltage balance, the power quality and cost saving [3]. Two types of harmonic filters are

- Passive Filter, and
- Active Filter

Among these methods, Passive Filters are applied to minimize harmonic distortions at No (3).Steel Mill (Ywama, Yangon) in this paper. Passive filters use a combination of reactors and capacitors to filter out harmonic frequencies.

3. PASSIVE FILTER

One classical solution to mitigate power grid distortions is passive filters which can flow the harmonic distortions to a low impedance ground way in a parallel link or dissipate it at high impedance in a series connection. The function of passive filters is to absorb the load harmonic currents, preventing them from circulating through the electrical system [5].The aim of harmonic filters is to reduce the negative effects of harmonics in current or voltage. Passive filters are inductance, capacitance and resistance elements configured and tuned to control harmonics. Passive harmonic filters are the most commonly used filters in industry. Several parallel-connected branches of filters are required to reduce more than a number of harmonic orders. Passive filter are used in power systems for decreasing voltage distortion and for power factor correction [8]. Common type of passive filter configurations is shown in Fig.2.

Classification of Passive Filter:

- Passive series filter
- Passive shunt filter
- Passive hybrid filter
- Techniques of passive Filters
- Single-Tuned filter
- High-pass filter(first, second or third order)

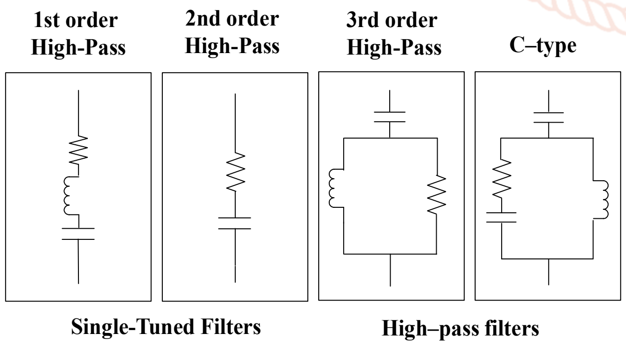

Fig.2 Common Passive Filter configurations

Passive filter is to be connected at the utility site of the system as shown in Fig.3:

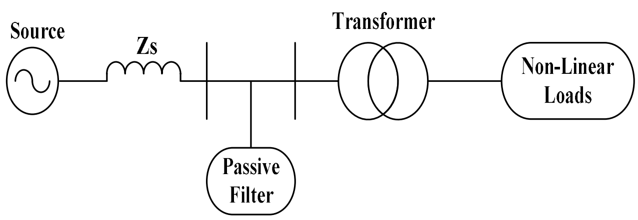

Fig.3 Block Diagram for the application of Shunt Passive Filter

4. Case Study

The No.3 Steel Mill (Ywama, Yangon) is chosen as case study area. This is located at Between Bayintnaung Road and Hlaing River, West Ywama Quarter, Insein Township, Yangon, Myanmar. It is produced many steel products such as Steel Billet (130×130×12,000mm Billets),Wire Nail, Barbed Wire, Square Mesh, Chain Link and Blade Wire. Since the dominant load of this No (3) Steel Mill (Ywama, Yangon) is industrial load. Most of the industrial loads are non-linear loads which cause malfunctioning of the loads connected at the PCC. Therefore, active filter can be used for minimizing the harmonic current injected at PCC by an industry of arc furnace. Incoming line of No (3) Steel Mill (Ywama,Yangon) is 66 kV bus bar of Hlawgar substation is stepped down by using 66 to 33kV transformer to 33kV. And then, 33kV voltage level is again stepped down to 11kV voltage level. In 11 kV main distribution feeder, two sections are separately operated as seen in Figure 5.

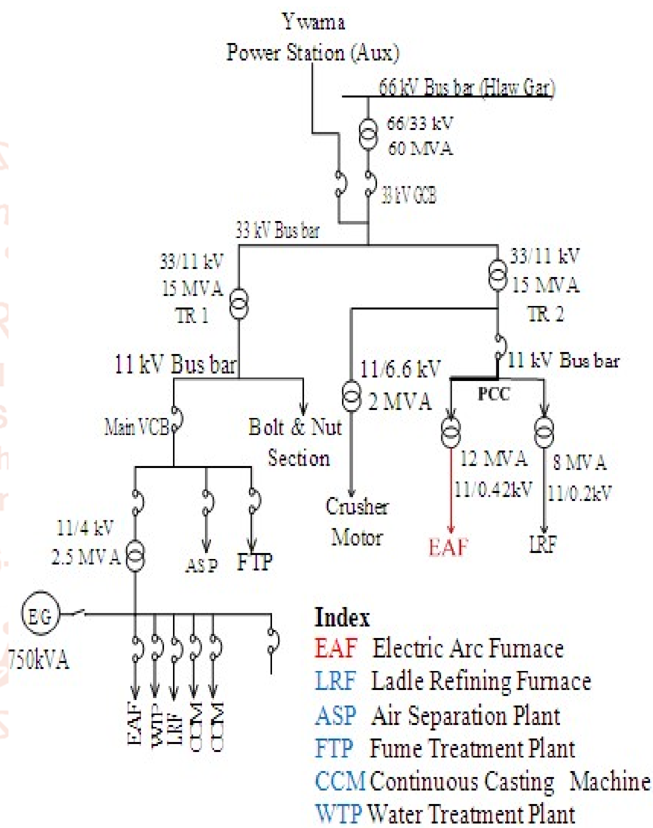

Fig.4 Single Line Diagram of No (3) Steel Mill (Ywama, Yangon)

The department EAF is operated at the 11kV (11MVA) bus bar. In fact, an electric arc furnace is a non-linear, time-varying load, which gives rise to harmonics. The electric arc itself is actually best represented as a source of voltage harmonics. The cause of harmonics is mainly related to the non-linear voltage-current characteristic of the arc while the voltage fluctuations are due to the arc length changes that occur during the melting of the scrap. The current and voltage harmonic distortion causes several problems in electrical power systems, such as incorrect operation of devices, premature ageing of equipment, and additional losses in transmission and distribution networks, overvoltage and over current.

The following Fig.5 is shown the model of No (3) Steel Mill (Ywama, Yangon) without filter:

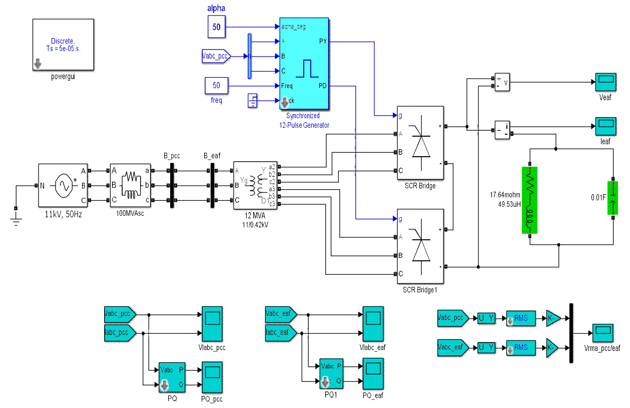

Fig.5 Modelling of No (3) Steel Mill (Ywama,Yangon) without filter

The following tables are showing the total voltage and current harmonic distortion levels in No (3) Steel Mill (Ywama, Yangon) without filters.

TABLE.I VOLTAGE DISTORTION LEVELS IN NO (3) STEEL MILL (YWAMA, YANGON) WITHOUT FILTER

	V_5	V_7	V_{11}	V_{13}	$THD_V(\%)$
Bus PCC	0.12%	0.23%	7.31%	6.54%	10.94%
Bus EAF	0.12%	0.23%	7.31%	6.54%	10.94%

The simulation voltage waveform without filter is shown in Fig.6.

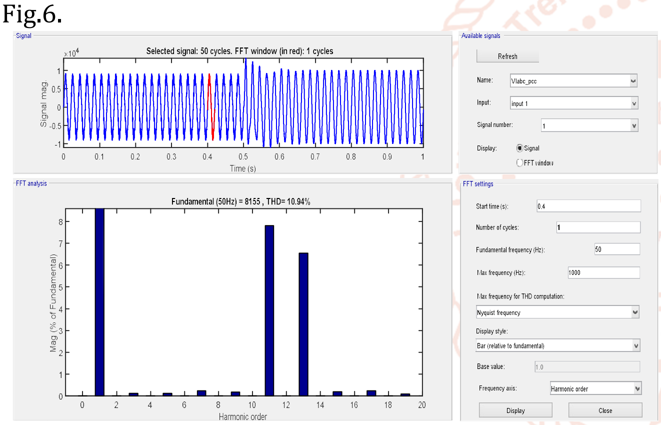

Fig.6 Total Harmonic Voltage Distortion% without Passive Filter by using FFT Analysis at PCC

TABLE.II CURRENT DISTORTION LEVELS IN NO (3) STEEL MILL (YWAMA, YANGON) WITHOUT FILTER

	I_5	I_7	I_{11}	I_{13}	$THD_I(\%)$
Bus PCC	0.21%	0.29%	6.38%	4.49%	7.88%
Bus EAF	0.21%	0.29%	6.38%	4.49%	7.88%

The simulation current waveform without filter is shown in Fig.7.

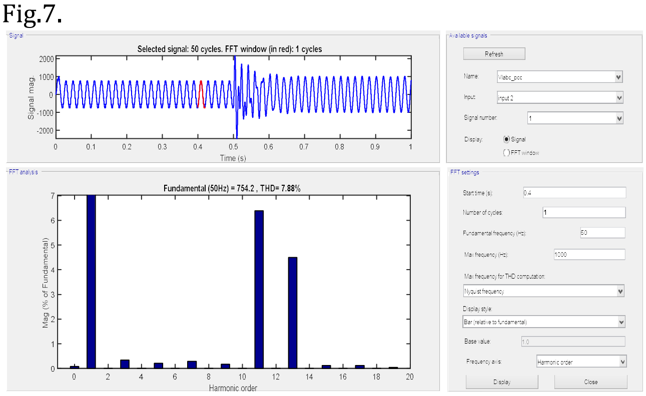

Fig.7 Total Harmonic Current Distortion% without Passive Filter by using FFT Analysis at PCC

Without filters, the total harmonic distortion of the voltage and current is above the range specified by the power quality standards. According to the results, the THD% of voltage and current exceeds the acceptable limits within IEEE 519-1992 standards for voltage and current in No (3) Steel Mill (Ywama, Yangon). The dominant orders are the 5th, 7th, 11th and 13th harmonic orders. Therefore, it is need to reduce these orders that the 5th, 7th, 11th and 13th orders have to be mitigated. Passive filters are installing for mitigating the harmonic distortion.

IEEE Std 519-1992 is recommended limits for maximum voltage distortion limits in Electrical Power Systems" [6].

TABLE.III IEEE STANDARD 519-1992, RECOMMENDED LIMITS FOR MAXIMUM VOLTAGE DISTORTION LIMITS

Bus voltage at PCC	Individual Harmonic Voltage Distortion (%)	THD (%)
$V_n \leq 69kV$	3.0	5.0
$69kV < V_n \leq 161kV$	1.5	2.5
$V_n \geq 161kV$	1.0	1.5

The THD values are shown that they are exceed the IEEE 519-1992 standard. The individual harmonic distortion must be less than 3% and the total harmonic distortion must be less than 5%.This can be obtained by connecting the filters to the system. For reducing the THD of voltage and current below 5%and individual harmonic distortion must be less than 3%, the passive filters have been designed.

5. Shunt Passive Filter Design

Passive filter are connected in parallel with the system. The shunt may be grounded in one of its terminations, and then it will be passed only for the tuned harmonic current and a part of the fundamental current. The compensating current which is the output of the shunt passive filter is injected in PCC, by this process the harmonic cancellation take place and current between the sources is sinusoidal in nature. For current source type of harmonic producing loads, generally, passive shunt filters are recommended. However, the performance of these filters depends heavily on the source impedance present in the system, as these filter act as sinks for the harmonic currents. In general filter used in distribution system is passive shunt type filter. These filter apart from mitigating the current harmonics, also provide limited reactive power compensation and dc bus voltage regulation.

Now, it is an important issue that consumers should reduce their harmonic currents to satisfies some criteria of utility and prevent the system and apparatus from the damage by harmonics. Various methods can be applied to reducing the harmonic currents in consumers, among of these methods the shunt passive harmonic filters are most often used as low cost devices and can provide the reactive power compensation to systems simultaneously.

A. Single tuned filter

Single tuned filter is most common and inexpensive type of passive filter. Single tuned filters are the probably most common type of filter which is used in industry broadly for the harmonic mitigation. Single tuned filters are the simple series connection of R-C-L component and L-C component. This filter is connected in shunt with the power system and provided a low impedance path for current. The harmonic currents are diverted from their normal flow path on the line through the filter. Single tuned filters can provide good power quality and reactive power compensation [4]. Single tuned filter is shown in Fig.8.

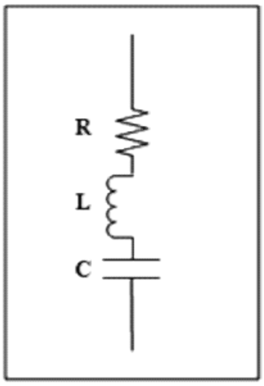

Fig.8 Single-Tuned Passive Filter

The utility grid voltage is normally assumed to be a pure sinusoidal at a fundamental frequency of 50 Hertz with 11kV (11MVA) bus bar. The No.3 Steel Mill (Ywama, Yangon) is chosen as case study area. A filter will be designed for an industrial facility and applied at 11V bus. The load where the filter will be installed is approximately 12MW with a relatively lagging power factor displacement of 0.75 (assume).

B. Design equation of harmonic filter

$$\text{Harmonic number, } h = \frac{\text{harmonic frequencies}}{\text{fundamental frequencies}} \quad (1)$$

- Reactive Power Compensation (Q_c)

$$Qc = \frac{V^2 n^2}{Xc(n^2 - 1)} \quad (2)$$

- Effective Reactive Power (Qeff)

$$Qeff = P\tan(\theta_1 - \theta_2) \quad (3)$$

- Effective Reactance (Xeff)

$$Xc = \frac{h^2}{h^2 - 1} \times X_{eff} \quad (4)$$

- Capacitive Reactance (X_c)

$$X_{eff} = \frac{(V_{1-1})^2}{Q_{eff}} \quad (5)$$

- Inductive Reactance (Xl)

$$X_1 = \frac{Xc}{h^2} \quad (6)$$

- Capacitance(C)

$$C = \frac{1}{2\pi f X_c} \quad (7)$$

- Inductance(L)

$$L = \frac{X_1}{2\pi f} \quad (8)$$

TABLE.IV CALCULATION RESULTS: PARAMETERS OF PASSIVE FILTER DESIGN

-	h=5	h=7	h=11	h=13
R(Ω)	1.116	0.608	0.217	0.155
C(mF)	0.129	0.191	0.133	0.134
L(mH)	3.552	1.935	0.69	0.493
Q_c(Mvar)	5.14	5.14	5.14	5.14

6. The Distribution System With Passive Filter

The four single tuned passive filters are designed to cancel the 5th, 7th, 11th and 13th harmonic orders. As the passive filter can be cancel the desired order and cannot control other the harmonic orders in power sections. The passive filters are installing at11kV feeder in No (3) Steel Mill (Ywama, Yangon). The following Fig.9 is shown the model of in No (3) Steel Mill (Ywama, Yangon) with passive filters.

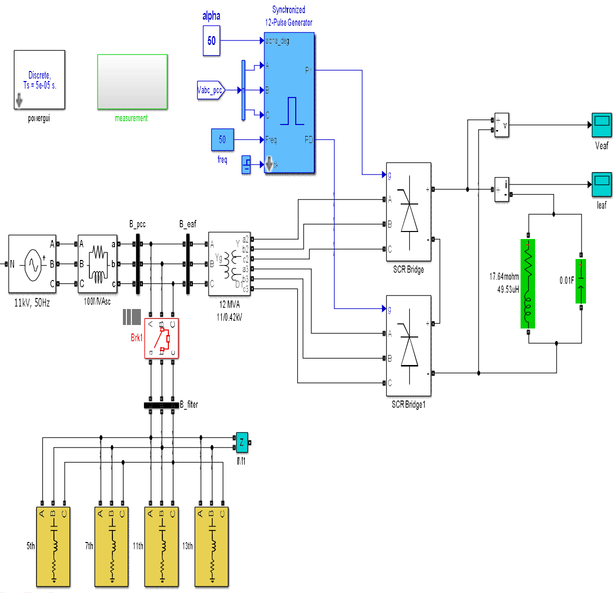

Fig.9 Modelling of No (3) Steel Mill (Ywama, Yangon) with passive filter

The simulation waveform with Passive Filter in No (3) Steel Mill (Ywama, Yangon) of distribution system is shown in Figures. The Fig.10 and 11 are showing the total voltage and current distortion wave forms with filters.

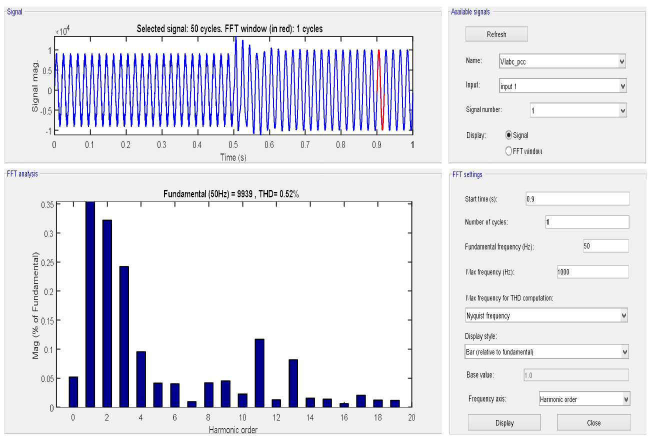

Fig.10 Total Harmonic Voltage Distortion% with Passive Filter by using FFT Analysis at PCC

After installing the passive filter, this passive filter is starting to operate 0.5 sec.

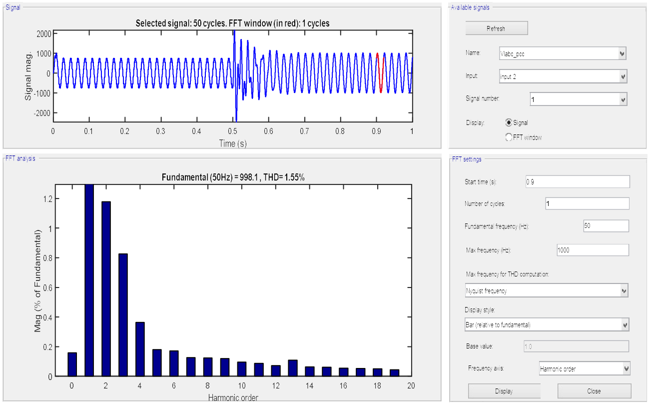

Fig.11 Total Harmonic Voltage Distortion% with Passive Filter by using FFT Analysis at PCC

The following tables are showing the total voltage and current harmonic distortion levels in No (3) Steel Mill (Ywama, Yangon) with Passive filters.

TABLE.VI VOLTAGE AND CURRENT DISTORTION LEVELS IN NO (3) STEEL MILL (YWAMA, YANGON) WITH PASSIVE FILTER

Harmonic orders	h=5	h=7	h=11	h=13	THD_V (%)
$THD_{V\%}$	0.04%	0.01%	0.12%	0.08 %	0.52 %
$THD_{I\%}$	0.18%	0.13%	0.09%	0.11 %	1.55 %

After installing the passive filters, the voltage and current of THD are significantly decline and waveforms are becoming sinusoidal in No (3) Steel Mill (Ywama).All of the results of THD% are acceptable limit of IEEE 519-1992 standards.

7. Conclusion

The main aim of this research is to minimize harmonic distortions in distribution network. The harmonics mitigation technique that is passive filter applied to No (3) Steel Mill (Ywama, Yangon) in distribution network are analyzed. The models are implemented for harmonic analysis of typical industrial loads in No (3) Steel Mill (Ywama, Yangon) distribution network. In No (3) Steel Mill (Ywama, Yangon) has the voltage distortion levels are over the acceptable limit under IEEE 519-1992 standards according to measure without filters. After installing passive filters, the voltage distortion and current distortion is under 3%. The results of THD are significantly decline in No (3) Steel Mill (Ywama, Yangon). Therefore, Passive filters can mitigate harmonic distortion.

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REFERENCES

[1] Arrillaga, J., Bradley, D. A. and Bodger, P.S., Power System Harmonic, John Wiley & Sons, U. S. A. (1985).

[2] Roger C. Dugan/ Mark. F. McGranaghan, Surya Santoso/H. Wayne Beaty, "Electrical Power System Quality".

[3] Francisco C. De La Rosa, Distribution Control Systems, Inc. "HARMONICS AND POWER QUALITY."

[4] J. Arrillaga, D. A. Bradley, and P. S Bodger, Power System Harmonics. New York: John Wiley & Sons, 1985, pp. 5-135.

[5] C. Venkatesh, "*Modelling of Nonlinear Loads and Estimation of Harmonics in Industrial Distribution System*", Fifteenth National Power Systems Conference (NPSC), IIT Bombay, December 2008.

[6] IEEE Std 519-1992, "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems", IEEE, New York, 1993.

[7] Antonio Cataliotti, Member, IEEE, and Valentina Cosentino "*A New measurement Method for the Detection of Harmonic Sources in Power.*"

[8] *Gonzalez, D. A. and Mccall, J. C., "Design of filters to reduce harmonic distortion in industrial power systems," IEEE Trans. On Industry Applications, Vol. IA-23, pp. 504-511 (1987).*

[9] D. J. Carnavole, "Applying Harmonic Solutions to Commercial and Industrial Power Systems", Eaton | Cutler-Hammer, Moon Township, PA, 2003

[10] J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," *IEEE Trans. Electron Devices*, vol. ED-11, pp. 34-39, Jan. 1959.

[11] C. Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, and M. Miller, "Rotation, scale, and translation resilient public watermarking for images," *IEEE Trans. Image Process.*, vol. 10, no. 5, pp. 767-782, May 2001.