MODELING AND HARMONIC ANALYSIS FOR DISTRIBUTION NETWORK IN MYANMAR

KhineZar Maw
Department of Electrical Power Engineering, Yangon Technological University, Myanmar

Abstract:* Power system harmonics are multiples of the fundamental power system frequency and these harmonic frequencies can create distorted voltages and currents. Distortion of voltages and currents can affect the power system adversely causing power quality problems. Non-linear devices such as power electronics converters can inject harmonics alternating currents (AC) in the electrical power system. To maintain the quality limits proposed by standards to protect the non-linear loads, it is necessary to include some form of filtering device to the power system. Filters have been devised to achieve an optimal control strategy for harmonic problems. In this paper, the case study is carried out at HlaingTharyar Township distribution system. The models are implemented for harmonic analysis of typical industrial loads in HlaingTharyar distribution network by using MATLAB / Simulink. Based on distortion, the filters have been designed. Passive filters are installing at point of common coupling (PCC) of each feeder in distribution substation (1) to reduce the harmonic distortion within IEEE 519-1992 standards.

***Keywords:* Electrical Distribution System, Nonlinear Load, Total Harmonic Distortion, Harmonic Filters**

I. INTRODUCTION

Electrical distribution systems are an essential part of the electrical power system. In order to transfer electrical power from an alternating current or a direct current source to the places those are industries, homes, and commercial buildings where it will be used. Distribution systems usually employ such equipment as transformers, circuit breakers, and protective devices. The distribution of electrical power in the Myanmar is normally in the form of three-phase 50 Hz alternating current. This power can be manipulated or changed in many ways by the use of electrical circuitry. The single-phase power is generally used for lighting and small appliances, such as those in the home or residential environments. The power distribution systems is to supply the electrical power necessary for industrial, residential, and commercial use. From the point of view of the system, the overallelectrical power system delivers power from the source to the load which is connected to it. Industries use almost 68% of all the electrical power produced, so three-phase power is distributed directly to most large industries. From these substations, power is distributed to industrial sites to energize industrial machinery, to residential homes, and to commercial users of electrical power. Harmonic is rising due to use of non-linear loads that from solid state components. In electrical power system distribution traditional equipments such as rotating machine produces harmonics due to uneven distribution of flux in air gap of rotating machine this tends to no sinusoidal voltage and current generation in rotating machine such a synchronous machine.

II. HARMONICS SOURCE ANDITS EFFECTS ON POWER SYSTEM

Harmonics are sinusoidal voltages or currents with frequencies that are integer multiples of the fundamental power frequency, which might be 50 or 60Hz. Harmonic frequencies from the 3rd to the 25th are the most common ones measured in electrical distribution systems. Harmonic distortion has been identified as existing within power systems. The harmonics can largely be attributed to the advancing power electronics usage and growth in the number of new load technologies connected to distribution systems. In general produce increased levels of harmonic current emissions that in turn raise the levels of harmonic voltages existing on the system.

Some of the more common power electronic loads include

- Switch mode power supplies - present in computers, televisions, microprocessors,
- Rectifiers – present in dc motor drives, regulated power supplies, battery chargers,
- Inverters – present in variable speed ac drives,
- Static VAr compensators,
- Cyclo-converters, and
- High voltage DC transmission converters.

Harmonics lists the following areas of harmonic effects are

- Failure of capacitor banks due to dielectric breakdown or reactive power overload;
- Interference with ripple control and power line carrier systems, causing misoperation of systems
- Excessive losses resulting in heating of induction and synchronous machines;
- Overvoltages and excessive currents on the system
- Dielectric breakdown of insulated cables resulting from harmonic overvoltages in the system;
- Inductive interface with telecommunication systems;
- Errors in meter readings;
- Signal interference and relay malfunction, particularly in solid state and microprocessor-control1ed systems;
- Interference with large motor controllers and power plant excitation systems;

III. HARMONIC MITIGATING TECHNIQUES APPLIED TO DISTRIBUTION NETWORK

Non-linear loads can inject the harmonic current into the supply system, depending on their loads. The substation and utility supply companies must ensure a certain voltage quality at the PCC (point of common coupling) in the distribution system that recommends the IEEE standard 519-1992. There are several basic methods for reducing harmonic voltage and current distortion from nonlinear distribution loads such as adjustable frequency drives (AFDs).

- Line reactors
- Isolation transformers
- 12 and 18 pulse rectifiers
- Harmonic filters
- Larger transformer (derated
- K-rated transformer

Among these methods, passive type filters are applied to HlaingTharyar Substation (1) in this paper.

A. Passive Filter

Passive elements like resistance, inductance and capacitance are used by the passive filters to control the harmonics. They are the most commonly used filters in industry. Three-phase harmonic filters are shunt elements that are used in power systems for decreasing voltage distortion and for power factor correction. Nonlinear elements such as power electronic converters generate harmonic currents or harmonic voltages, which are injected into power system. The resulting distorted currents flowing through system impedance produce harmonic voltage distortion. Harmonic filters reduce distortion by diverting harmonic currents in low impedance paths. The following equations are the calculation of the parameter of filter design.

Tuned Filter order

$$h = \frac{f_n}{f_1} = \sqrt{\frac{X_C}{X_L}} \quad (1)$$

Quality Factor

$$Q = \frac{nX_1}{R} \quad (2)$$

Reactive power at f_1 Qc

$$Q_c = \frac{V^2}{X_C} \cdot \frac{n^2}{(n^2 - 1)} \quad (3)$$

Active power at f1

$$P = Q_c \frac{n}{(n^2 - 1)} \cdot \frac{1}{Q} \quad (4)$$

IV. CASE STUDY

The detailed study is carried out at Hlaingtharyar distribution substation No (1). The substation is located at Hlaingtharyar Township, Yangon, Myanmar.

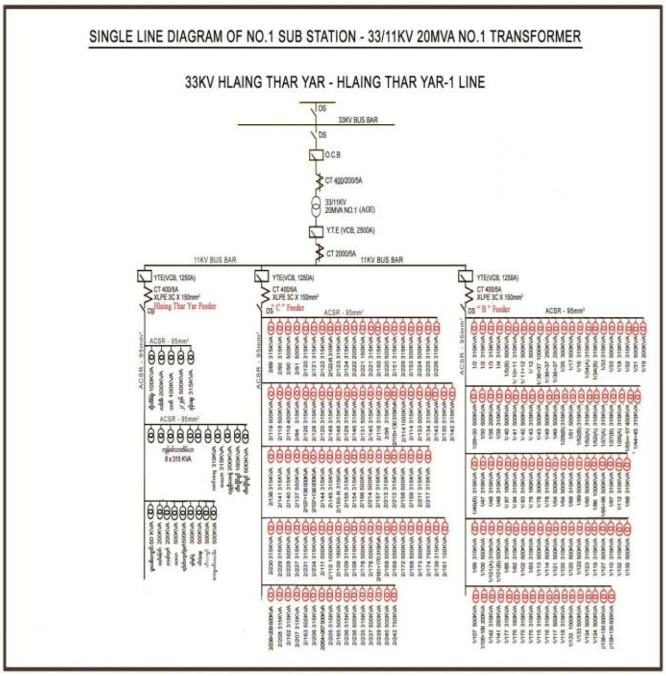

Fig. 1 [a] Sinle Line Diagram of No 1. Transformer in Hlaingtharyar Substation (1)

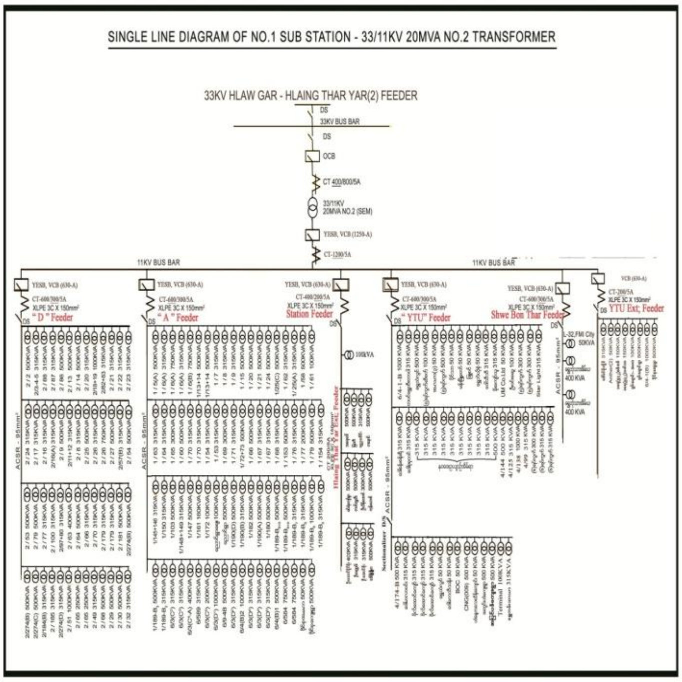

Fig. 1 [b] Single Line Diagram Of No 2. Transformer InHlaingtharyar Substation (1)

This substation is constructed for supplying the electric power to Hlaingtharyar industrial zone and some housing of Hlaingtharyar.Hlaingtharyar Industrial zone is the largest one in Myanmar. Since the dominant load of this substation is industrial load. The incoming line of substation No (1) is taken from 33 kV bus of Hlaingtharyar Primary substation which is located at west of Hlaingtharyar township. Substation No (1) comprise two number of 20 MVA, 33 kV/

11 kV transformers. There are eight number of 11 kV main distribution feeder which are connected to two separate 11 kV bus bar of substation No (1) as shown in Figure (1). The Figure 1 is showing the single line diagram of Hlaingtharyar substation (1).
The following table are showing the total voltage and current harmonic distortion levels in Hlaingtharyar substation (1) without filters.

Table 1. Voltage Distortion inHlaingtharyar Distribution Networks

	V_5	**V_7**	**V_{11}**	**V_{13}**	**THD_v %**
33kV	8.69	3.72	3.50	2.72	10.68
FeederA	10.23	4.45	3.87	3.10	12.46
FeederB	10.94	4.63	4.71	3.54	13.66
FeederC	10.94	4.63	4.71	3.54	13.66
FeederD	10.23	4.45	3.87	3.10	12.46

Table 2. Current Distortion in Hlaingtharyar Distribution Networks

	I_5	**I_7**	**I_{11}**	**I_{13}**	**THD_I %**
33KV	3.90	1.19	0.71	0.47	4.17
FeederA	4.60	1.93	1.35	0.84	5.35
FeederB	3.16	1.17	0.61	0.51	3.53
FeederC	5.09	2.01	1.79	0.79	5.98
FeederD	5.10	2.34	0.83	0.42	5.77

According to the results, the THD% of voltage and current exceeds the acceptable limits within IEEE 519-1992 standards for voltage and current in HTY substation. The dominant orders are the 5th,7th,11th and 13th harmonic orders. Therefore, it is need to reduce these orders thatthe 5th, 7th,11th and 13th orders have to be mitigated. Passive filters are installing for mitigating the harmonic distortion.The simulation waveform without filter is shown in figures.

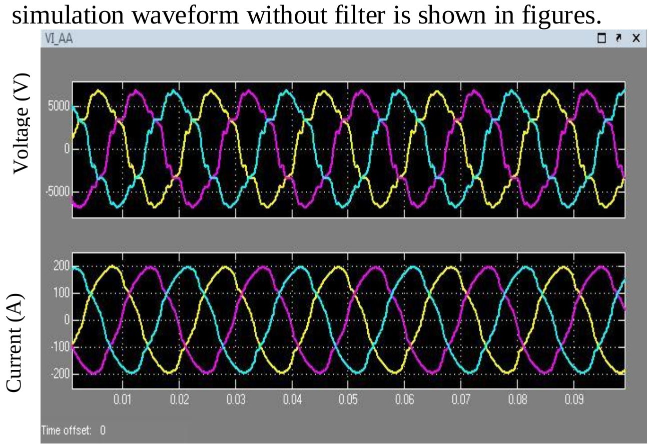

Figure 2.Voltage and current waveform of simulation results without inFeeder A

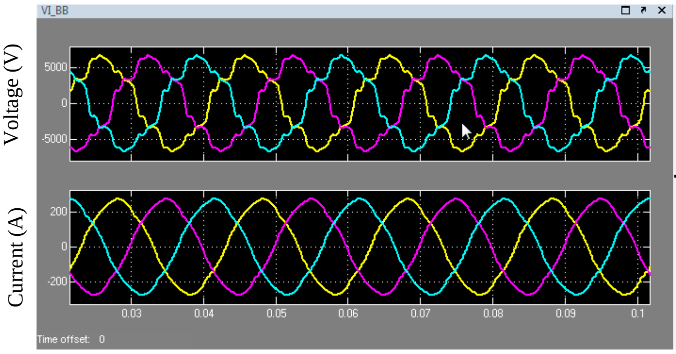

Figure 3.Voltage and current waveform of simulation results without Filter inFeeder B

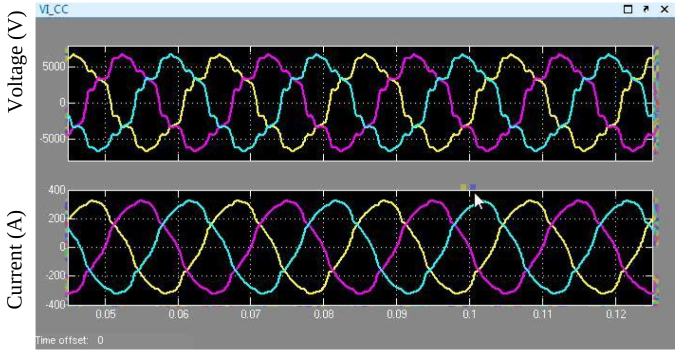

Figure 4.Voltage and current waveform of simulation results without in Feeder C

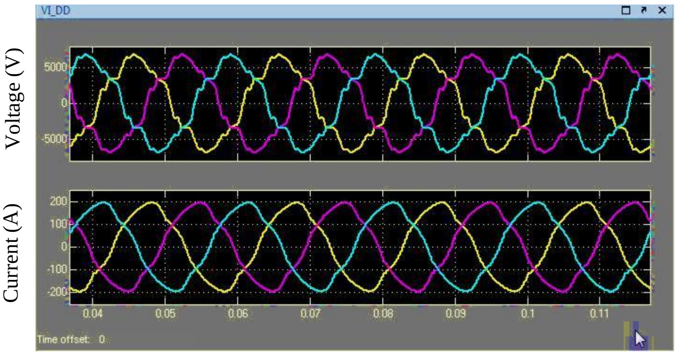

Figure 5.Voltage and current waveform of simulation results without in Feeder D

Without filters, the total harmonic distortion of the voltage and current is above the range specified by the power quality standards. The THD value of HTY substation (1) are shown that they are exceed the IEEE 519-1992 standard. To follow the recommended IEEE 519 power harmonic standards 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%, the filters have been designed.

V. 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 at each feeders in HlaingTharyar Substation (1).

Calculation results of the parameter of Filter Design

The four single tuned passive filters are designed to cancel the 5th, 7th, 11th and 13th harmonic orders.

Filter parameters are shown thefollowing tables.

Table 3. Filter Design Calculation in Feeder A

	h=5	h=7	h=11	h=13
R (Ω)	0.443	0.310	0.195	0.164
L (mH)	2.820	1.410	0.560	0.403
C (mF)	0.143	0.146	0.148	0.148

Table 4. Filter Design Calculation in Feeder B

	h=5	h=7	h=11	h=13
R (Ω)	0.301	0.211	0.132	0.112
L (mH)	1.910	0.957	0.383	0.273
C (mF)	0.211	0.216	0.218	0.219

Table 5. Filter Design Calculation in Feeder C

	h=5	h=7	h=11	h=13
R (Ω)	0.274	0.177	0.111	0.093
L (mH)	1.600	0.800	0.321	0.414
C (mF)	0.252	0.257	0.260	0.261

Table 6. Filter Design Calculation in Feeder D

	h=5	h=7	h=11	h=13
R (Ω)	0.496	0.346	0.217	0.184
L (mH)	3.148	1.570	0.629	0.449
C (mF)	0.128	0.131	0.133	0.449

The following figure is shown the model of Hlaingtharyar substation (1) with passive filters. The filters are installing the each feeder in substation.

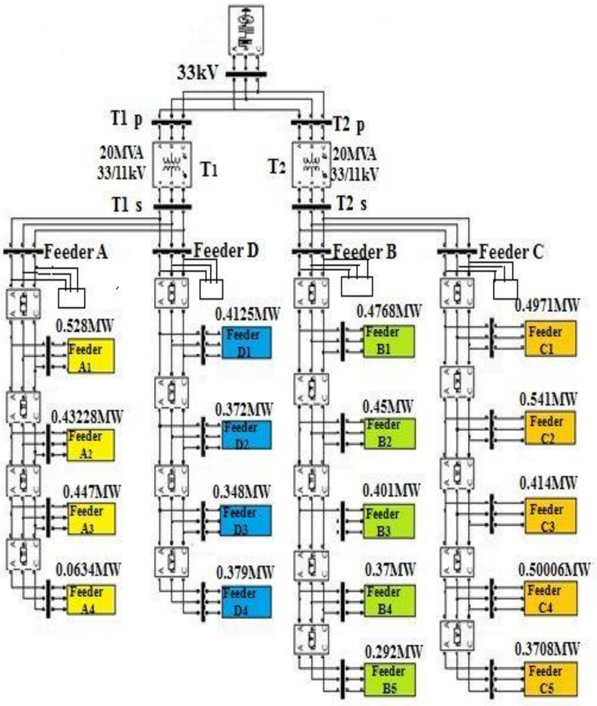

Fig.6.Modelling of HlaingTharyar Substation (1) with passive filters

The following Tables are showing the total harmonic voltage and current distortion with filters.

Table7.Voltage Distortion Levels in Hlaingtharyar Distribution Networks with Passive Filter

	V_5	V_7	V_{11}	V_{13}	THD_v %
33kV	1.95	1.35	0.23	0.22	2.51
FeederA	2.26	1.47	0.27	0.27	2.90
FeederB	2.46	1.77	0.32	0.28	3.19
FeederC	2.46	1.77	0.32	0.28	3.19
FeederD	2.26	1.47	0.27	0.27	2.90

Table8.Current Distortion Levels in Hlaingtharyar Distribution Networks with Passive Filter

	I_5	I_7	I_{11}	I_{13}	THD_I %
33KV	0.95	0.47	0.05	0.03	1.06
FeederA	2.07	1.03	0.88	0.64	2.77
FeederB	0.30	0.16	1.06	0.65	1.59
FeederC	2.33	1.77	1.03	0.71	3.05
FeederD	0.61	0.29	0.69	0.01	1.64

The simulation waveform with filter in distribution substation(1) is shown in Figures. The Figuresare showing the total voltage and current distortion wave forms with filters. These passive filters are starting to operate 0.2 sec.

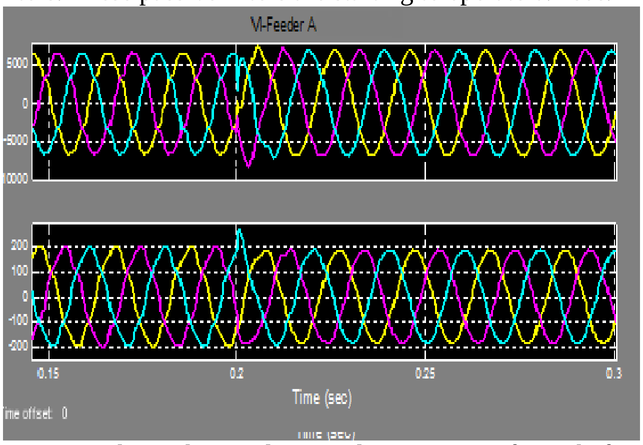

Figure.7. The 3-phase voltage and current waveforms before and after passive filter at Feeder A

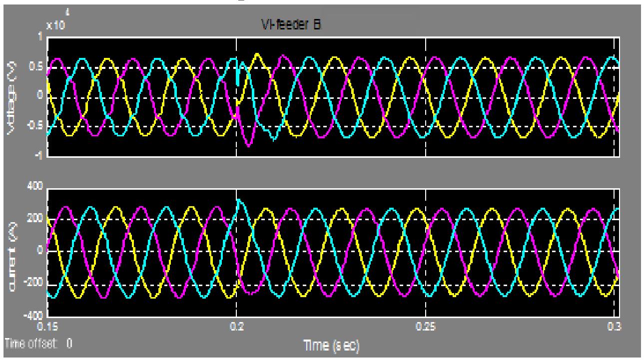

Figure 8. The 3-phase voltage and current waveforms before and after passive filter atFeeder B

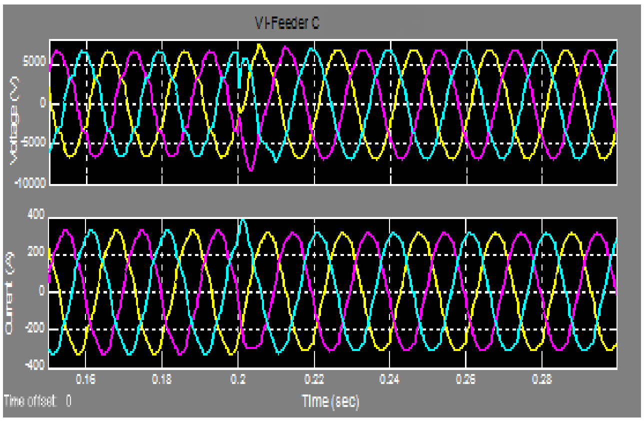

Figure 9.The 3-phase voltage and current waveforms before and after passive filter at FeederC

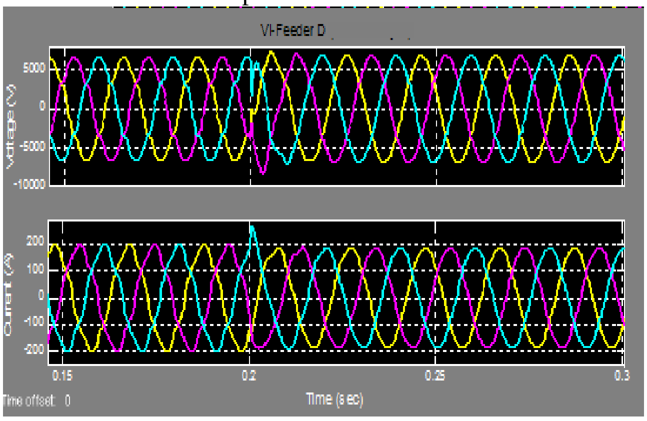

Figure10. The 3-phase voltage and current waveforms before and after passive filter atFeederD

After installing the passive filters, the voltage and current of THD are significantly decline and waveforms are becoming sinusoidals in HlaingTharyar Substation.All of the results of THD% are acceptable limit of IEEE 519-1992 standards.

VI. DICUSSIONS

Under Substation (1) distribution network, there are about 300 industries and other are commercial, domestic building and they are almost using in non-linear loads. Due to the use of increasing the non-linear loads, distorted voltage and current are cause to be harmonics. That can be effected power system quality and reduced the power system performance. The control or mitigation of the power quality problems may be realized to use mitigation techniques applied in distribution system. The mitigation technique is filtering methods that may reduce harmonic levels to below IEEE 519guidelines.

VII. CONCLUSIONS

In this paper, harmonics mitigation technique that is passive filter applied to HlaingTharyar distribution network are analyzed. The models are implemented for harmonic analysis of typical industrial loads in HlaingTharyar distribution network.In Hlaingtharyar Substation (1) has the voltage distortion levels are over the accepatablelimit 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 Hlaingtharyar Substation. Therefore,Passive filters can mitigate harmonic distortion.

Acknowledgments
The author wishes to express her deepest gratitude to all respectful teachers in Electrical Engineering Department in Yangon Technological University, for continuous guidance, suggestion and advice to this paper. Similar thanks to all teachers for their instructions and willingness to share their ideas thought all those years of study. Thanks are also extended to her dear parents for their support and help during the thesis and givingsuggestions.

REFERENCES

[1] Antonio Cataliotti, Member, IEEE, and Valentina Cosentino "A New measurement Method for the Detection of Harmonic Sources in Power
[2] J. Arrillaga, D.A. Bradley, and P.S Bodger, Power System Harmonics. New York: John Wiley & Sons, 1985, pp. 5-135.
[3] IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems". IEEE Std 519 – 1992.
[4] IEEE/CIGRE Joint Task Force on Stability Terms and Definitions, "Definition and Classification of Power System Stability", IEEE Trans-actions on Power Systems, Vol. 5, No. 2, May 2004, pp. 1387–1401.
[5] "IEEE Recommended Practice for Electric Power Distribution for Industrial Plants", IEEE Std 141-1993 (Revision of IEEE Std 141-1986

