ANALYSIS OF THE EFFECT OF TOTAL HARMONIC DISTORTION ON LOSSES AND EFFICIENCY OF THREE PHASE INDUCTION MOTOR

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Abstrak

Motor induksi tiga fasa banyak digunakan sebagai penggerak utama pada mesin industri. Motor induksi tiga fasa ini di rancang untuk mendapatkan tegangan masuk yang sinusoidal. Motor induksi dalam pengoperasiannya juga menghasilkan harmonisa. Hal ini karena pada pembuatannya, motor induksi menggunakan material ferromagnetic yang menghasilkan kurva B-H yang tidak linier sehingga menimbulkan efek saturasi. Dampak harmonisa pada motor induksi adalah meningkatnya rugi-rugi motor induksi dan juga menurunnya efisiensi motor. Selain itu harmonisa ini menimbulkan torsi harmonisa yang bersamaan dengan torsi fundamental yang menghasilkan getaran yang pengaruhnya cukup besar pada operasi motor. Dalam penelitian ini, digunakan aplikasi Simulink Matlab untuk membuat simulasi rangkaian harmonisa pada motor listrik tiga fasa. Keluaran total distorsi harmonisa sebisa mungkin tidak melebihi standar total distorsi harmonisa pada IEEE 519-2014 yaitu 5%. Pengamatan dilakukan pada parameter motor listrik yaitu kecepatan, torsi, efisiensi, dan rugi-rugi motor. Rata-rata nilai efisiensi pada setiap orde sebesar 70%. Semakin besar harmonisa pada rangakian,maka nilai losesnya juga akan besar. Besarnya harmonisa juga berpengaruh pada RPM dan torsi motor.

Kata Kunci: Motor, Rugi-rugi, Efisiensi, Harmonisa

Abstract

Three-phase induction motors are widely used as prime mover in industrial machines. This three-phase induction motor is designed to have a sinusoidal input voltage. Induction motor in its operation also produces harmonics. This is because in its manufacture, the induction motor uses a ferromagnetic material which produces B-H curve that is not linear, causing a saturation effect. The impact of harmonics on an induction motor is an increase in induction motor losses and also a reduction of motor efficiency. In addition, this harmonic generates harmonic torque along with fundamental torque which results in vibrations which have a significant influence on motor operation. In this research, the Simulink Matlab application was used to simulate a harmonic circuit in a three phase electric motor. The total output of harmonic distortion as much as possible does not exceed the standard of total harmonic distortion in IEEE 519-2014 which is 5%. Observations were made on the parameter of the electric motor, namely RPM, torque, efficiency, and motor losses. The average value of efficiency in every order is 70%. If the value of harmonic is high, so the value of losses is also high. RPM and torque is influence by harmonic.

Keyword: Motor, Losses, Efficiency, Harmonic

1. INTRODUCTION

In the industrial area, a product is resulted from raw material, that through some process which is called production process. Every industry has the different part of process, based on the kind of product.

The industrial production machines, is moved by electric motors, where the kind of electric motor that usually used is induction motor. A lot of 3 phase induction motor utilization in the industry, because of some benefit which is the cheap price, the simple construction, and the easy maintenance, when it is compared with the other kinds of electric motor.

Three-phase induction motor is electrical machine that changes electric energy become mechanical energy in the form of rotation of motor through the electromagnetic induction principles. The electromagnetic induction principles cause induction motor has the saturation character, that is a situation where in the certain point, the electric current that resulted is does not comparable to the voltage increasing that give to the motor, and even tent constantly, because of the saturation characteristics so induction motor is grouped in the non-linear load.

In the electric power system, non-linear load resulting a harmonics, that is the wave that has frequency with multiple frequency from the basic frequency. The harmonic influence on the electric power system is the increasing of impedance transmission line system so that increasing copper losses and flux. On the power transformer would increasing the iron losses, leakage current and insulation stressed so that impact overheat on the power transformation. On the load side of harmonics influence, cause abnormal work of electric device.

On the measuring of harmonics, use the specific tools that know the harmonic order that arise and harmonic level that caused. The main source of harmonic on the conventional power system is non-linear load. Non-linear load cause variation of current not comparable to voltage during every period, so that current and voltage will distorted.

2. METHOD

This research will make a design of 3 phase induction motor in Simulink MATLAB. To get the analysis of the research, the following part is:

1. Creating the design system of three phase induction motor in Simulink MATLAB
2. Simulation methodology
3. Simulation analysis
4. Result and discussion

The stage of this research are shown in figure 1.

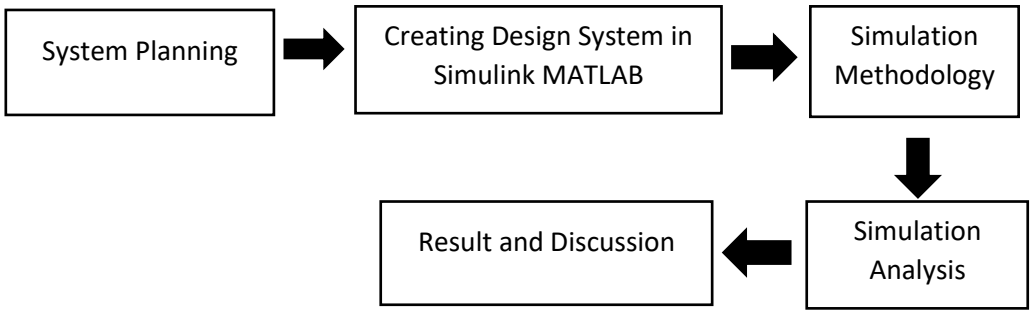

Figure 1. Stage of Research

After make the design system of three phase induction motor in Simulink MATLAB, simulate the design with FFT. FFT is algorithm to calculate DFT (Discrete Fourier Transform) and this inverse. Fourier transform change the time domain on the frequency domain or the otherwise.

2.1 System Planning

The first method that will be used in the system is creating a flowchart in order to displays the order of part that will do.

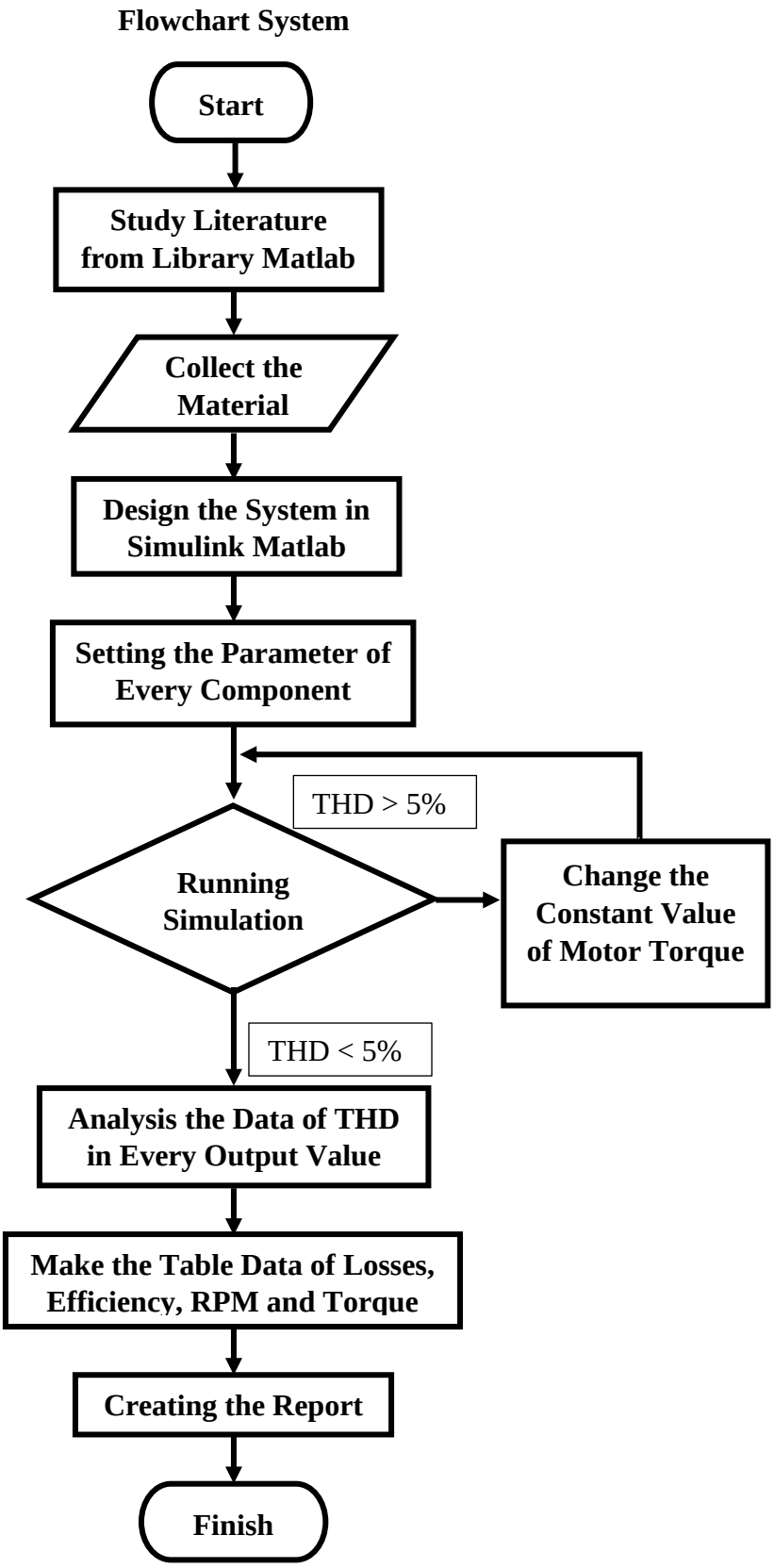

Figure 2. Flowchart of Research Methods

Flowchart of three phase induction motor system for analyse of the effect of harmonic distortion on THD using Simulink MATLAB is explained in figure 2.

2.2 Simulation methodology

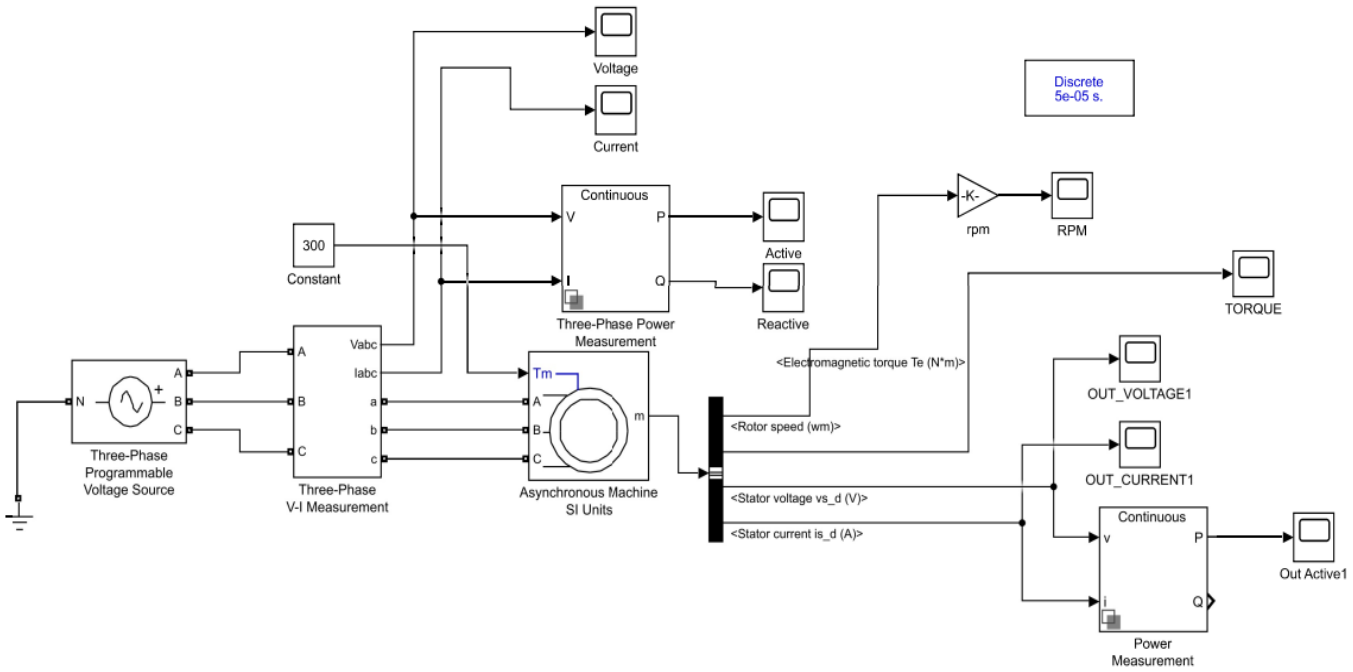

Figure 3. Simulation Design on Simulink MATLAB

2.3 Analysis Simulation

The system design consist of several component that inside in SimPowerSystem block. Three-phase Programmable Voltage Source is a Three-Phase power supply block (phase A, B, C, and neutral) where it can be set it amplitude (V), angle, and Frequency (Hz).

Three-Phase V-I Measurement is the instrument block that can emit the data parameter of Three-Phase source, the voltage (V) and current (I). Three-Phase Power Measurement is the block that used to change three-phase voltage and current unit become reactive and active power unit. The value of reactive and active power that produce by Three-Phase Power Measurement is showing by reactive scope and active scope, and also record the data value based on time setting and carry out FFT (Fast Fourier Transform) to search harmonic THD (Total Harmonic Distortion).

Asynchronous Machine SI Units, is the block of Three-Phase asynchronous motor. is the main object of this research that will be search the value of speed (RPM) and Torque (Nm). The bus selector block is used to separate the output function of the motor, in order to emit the speed (RPM) and Torque (Nm) value of the motor. The oscilloscope is to show the data in the form of wave.

3. RESULT

3.1. Simulation Result

This simulation using FFT method. The result of THD simulation is shown in the picture and table as follows :

1. Voltage (V_{THD})

a. Voltage signal measurement

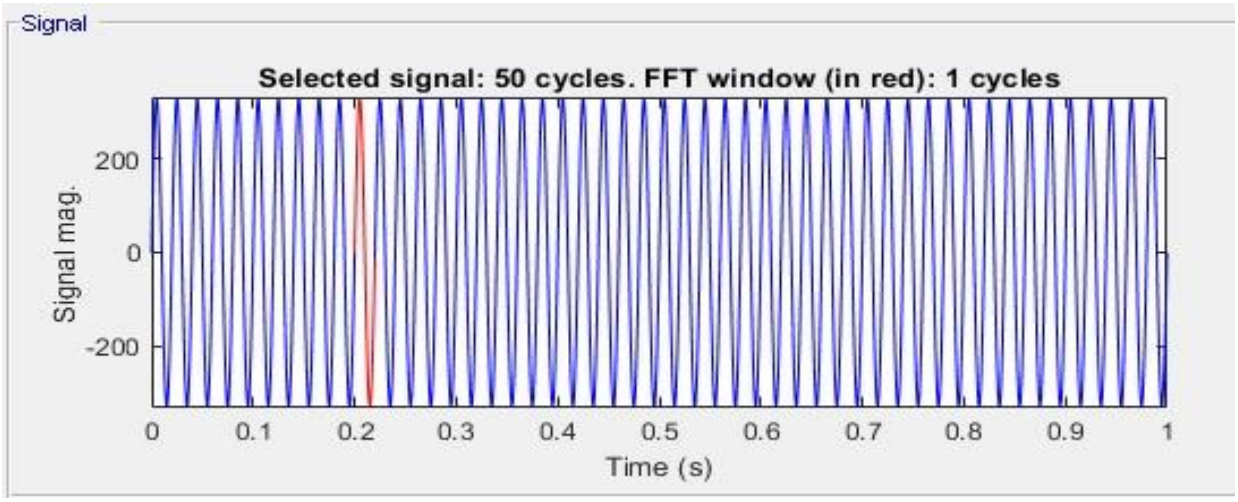

Figure 4. Voltage Signal Measurement

b. Voltage Harmonic Order (V_{THD})

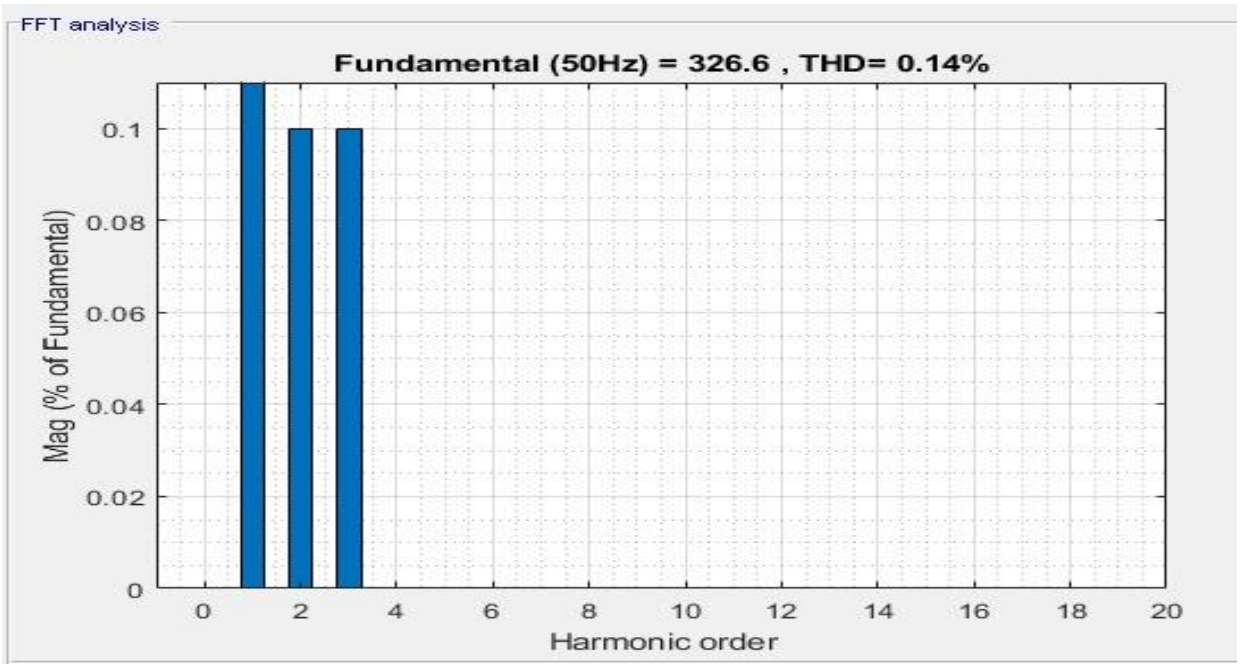

Figure 5. Voltage Harmonic Order

c. Voltage Nyquist

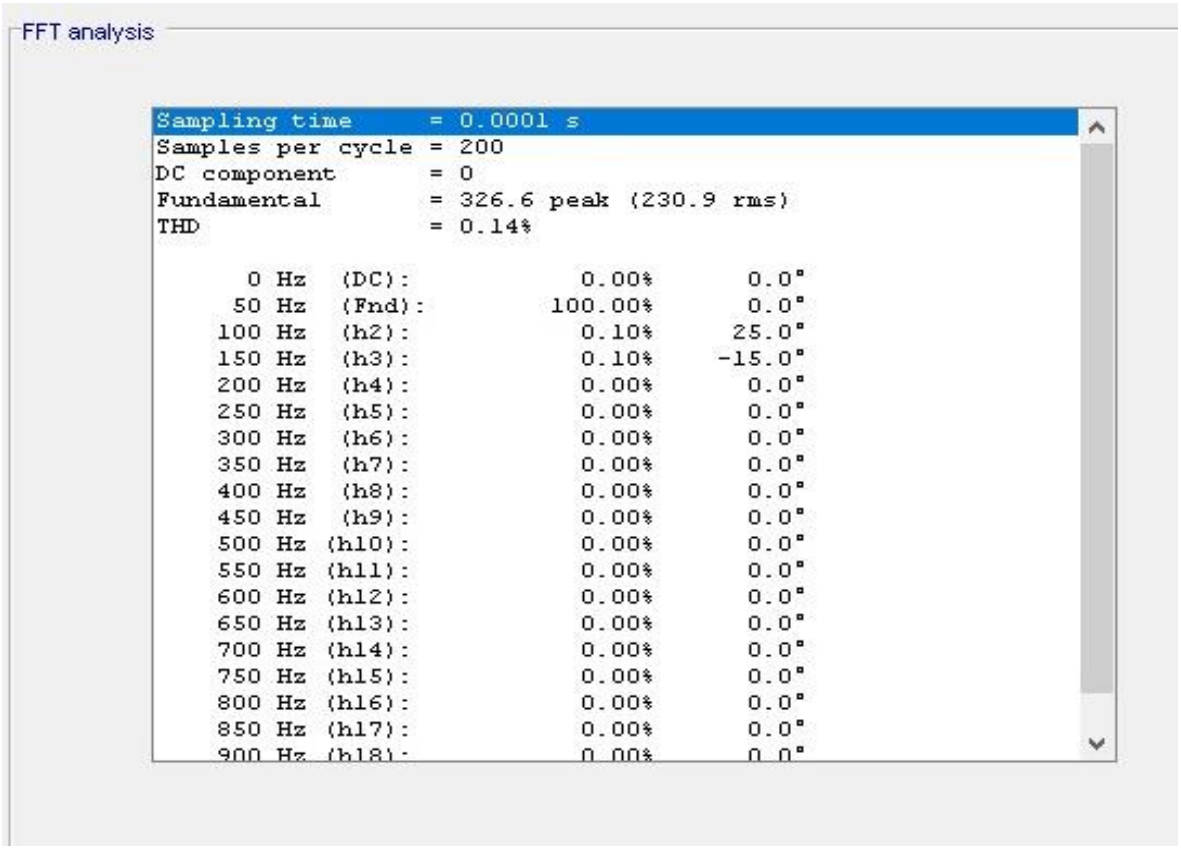

Figure 6. Voltage Nyquist

2. Current (I_{THD})

a. Current Signal Measurement

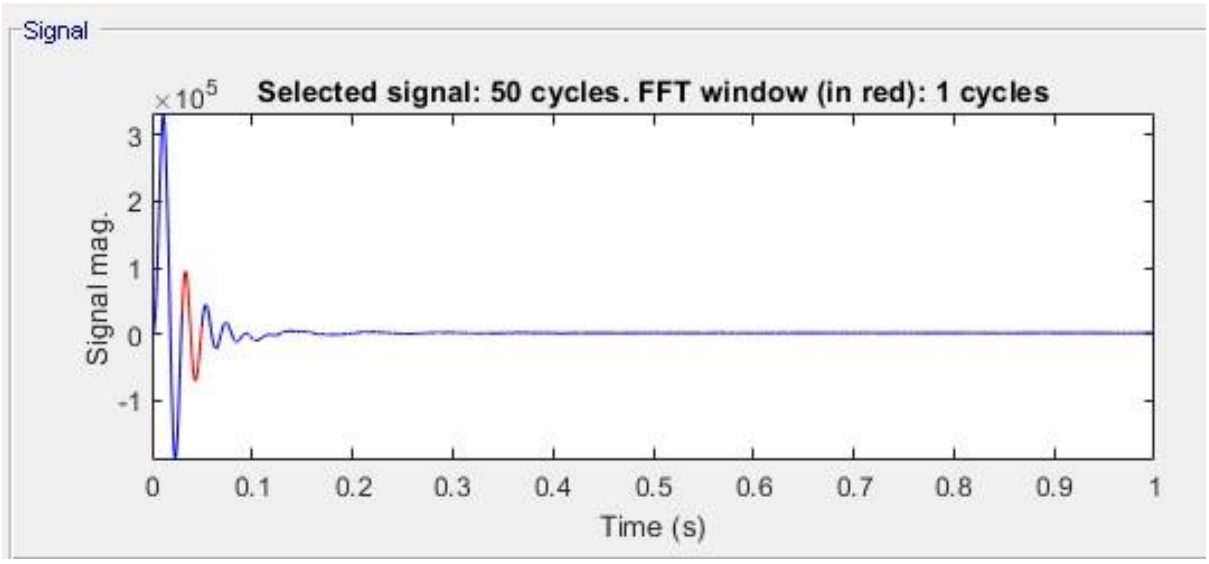

Figure 7. Current Signal Diagram

b. Current Harmonic Order (I_{THD})

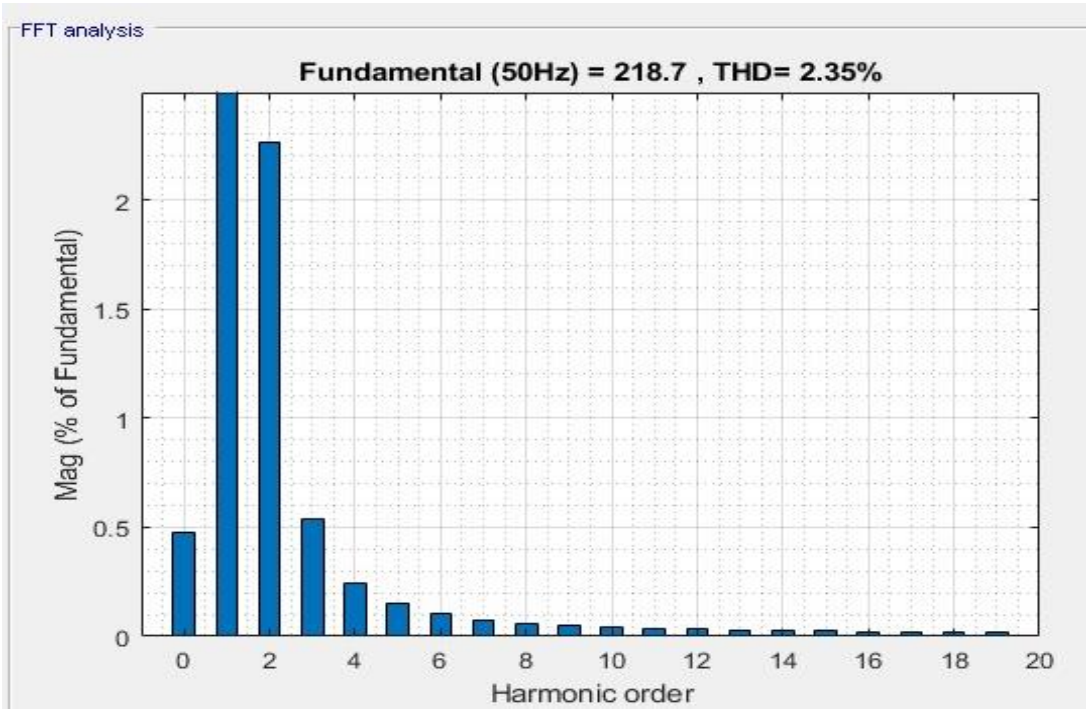

Figure 8. Current Harmonic Order

c. Current Nyquist Frequency

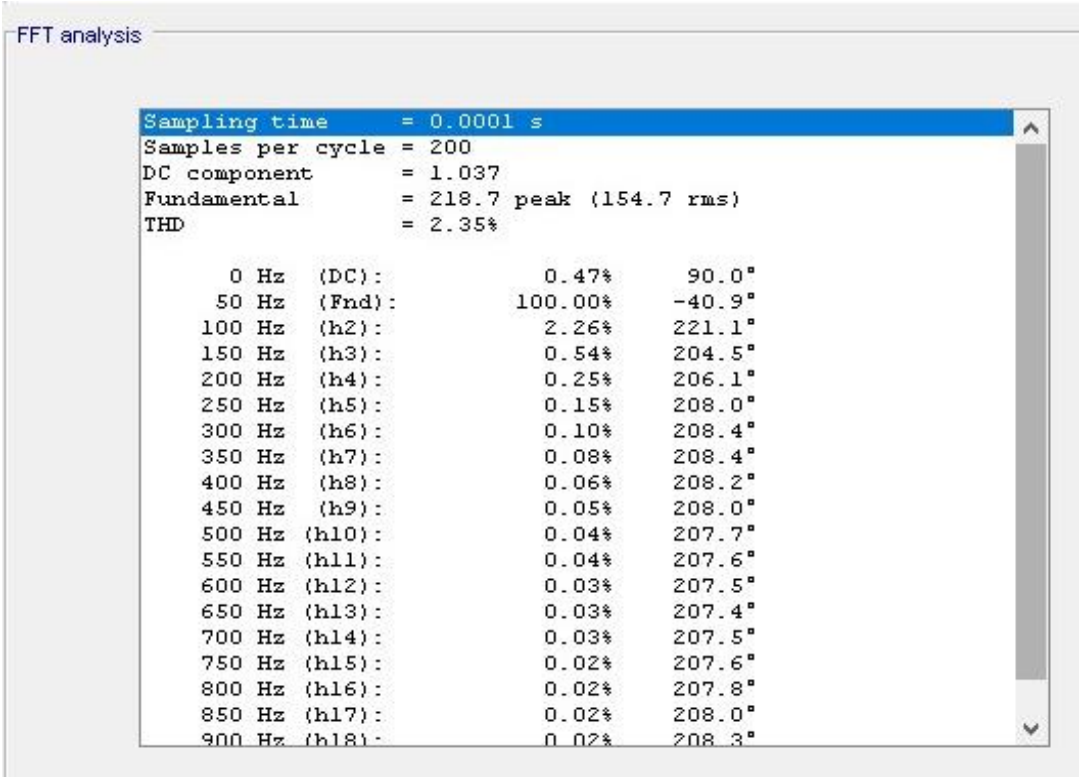

Figure 9. Current Nyquist Frequency

3. Active Power (P)

a. Active Power Signal Measurement

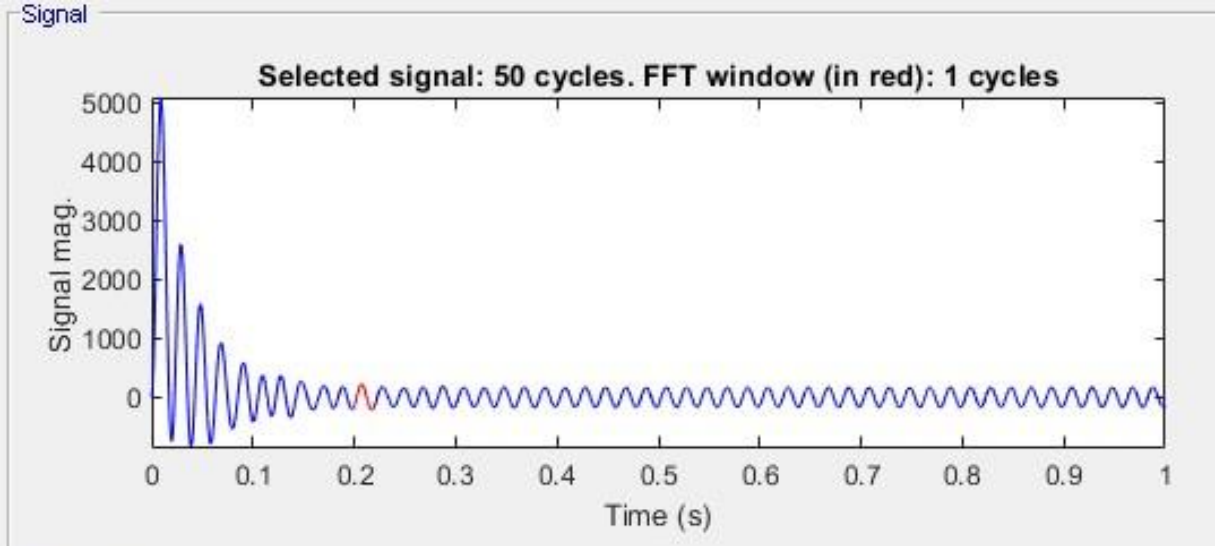

Figure 10. Active Power Signal Measurement

b. Active Power Harmonic Order (p)

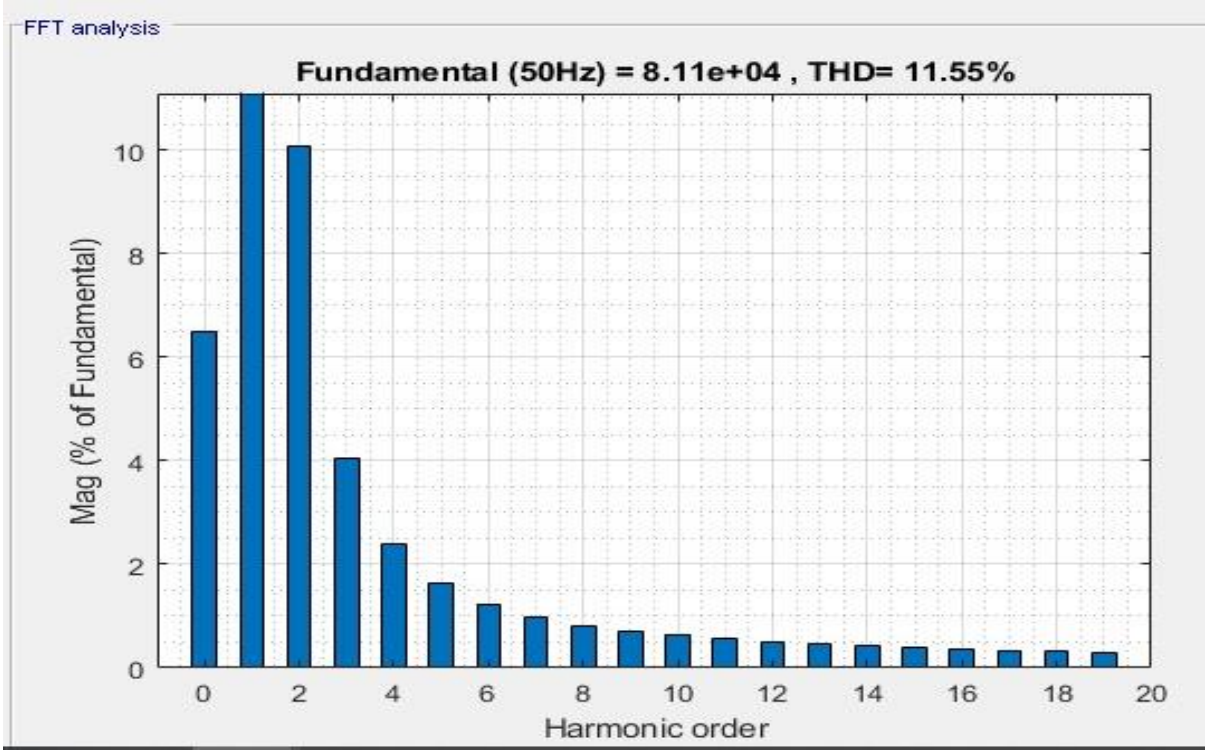

Figure 11. Active Power Harmonic Order

c. Active Power Nyquist Frequency (p)

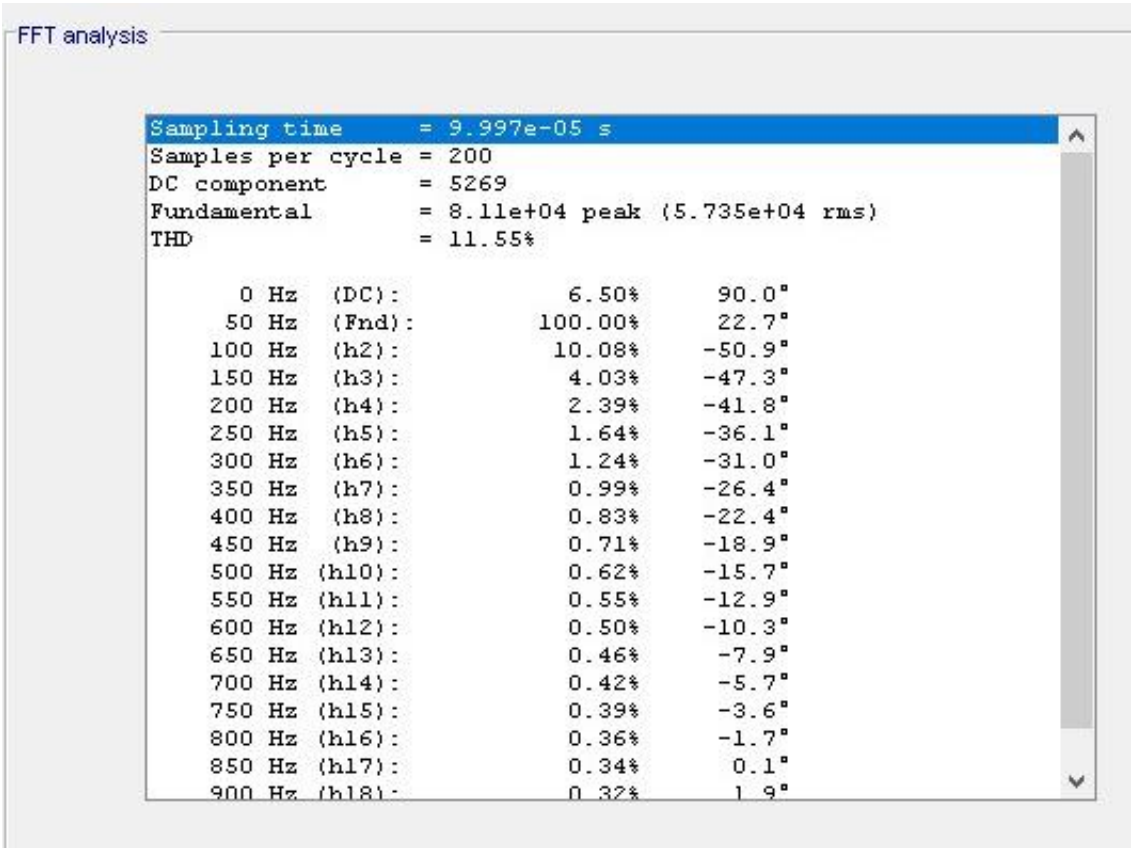

Figure 12. Active Power Nyquist

4. Reactive Power (Q)

a. Reactive Power Signal Measurement

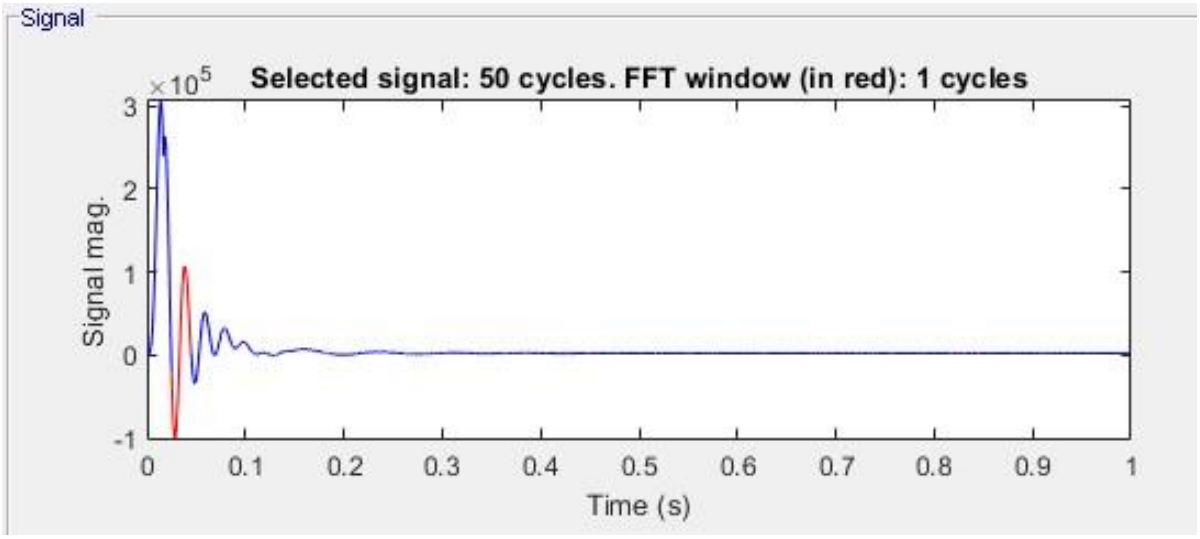

Figure 13. Reactive Power Signal Measurement

b. Reactive Power Harmonic

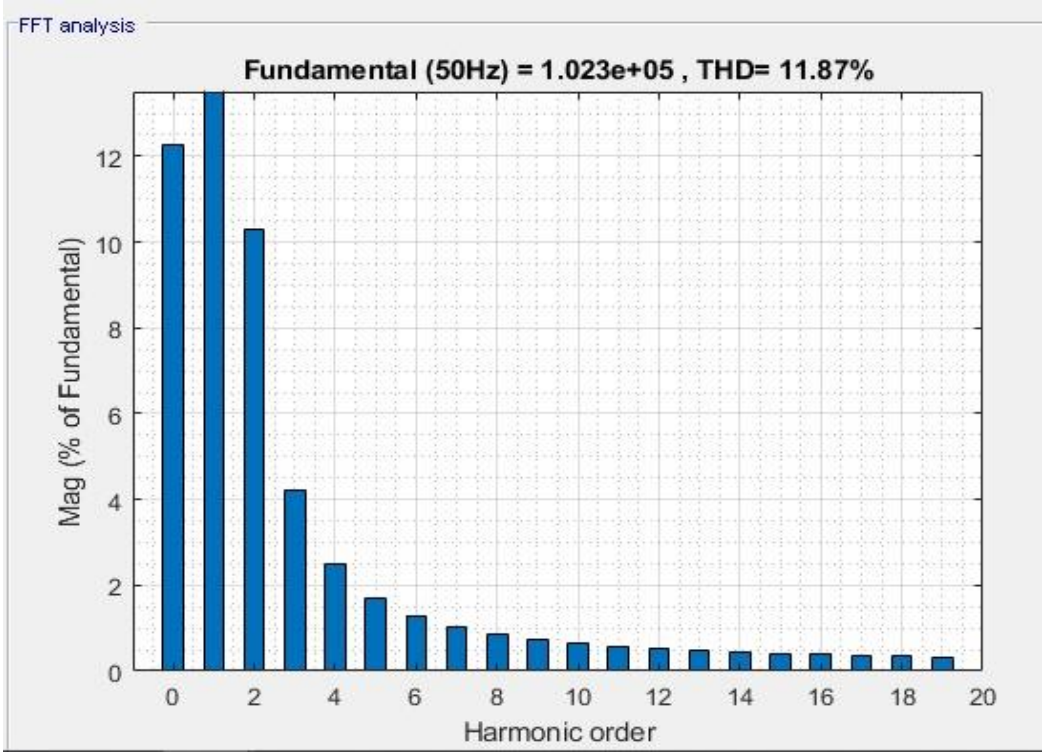

Figure 14. Reactive Power Harmonic Order

c. Reactive Power Nyquist Frequency

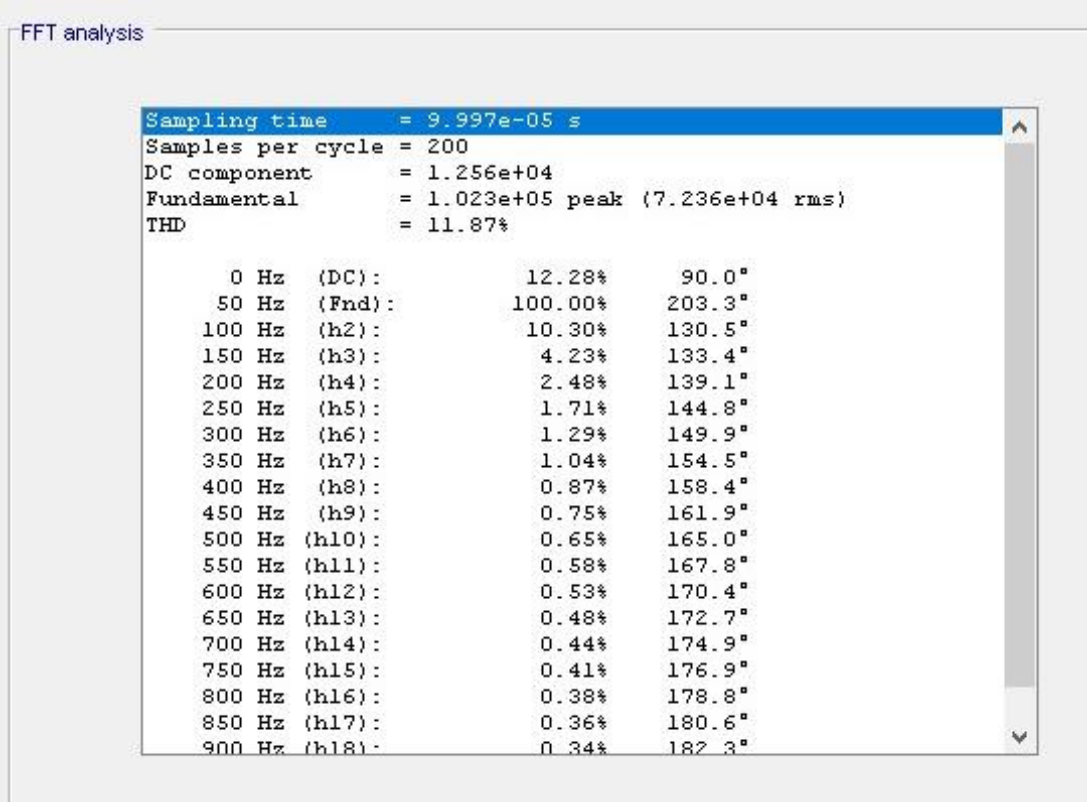

Figure 15. Reactive Power Nyquist

3.2 Simulating Result THD

Phase	V_{THD} (%)	I_{THD} (%)
R	0.14 %	2.35 %
S	0.14 %	2.35 %
T	0.14 %	2.35 %
Average	0.14 %	2.35 %

Table 1. Result of THD Simulation

$V_{RMS} = 326.6$ V

$I_{RMS} = 218.7$ A

3.3 Analysis

IEEE 519-2014 Based of Standard Harmonic

Standard VTHD IEEE 519-2014 : based on IEEE standard 519-2014 about the maximum limit value of the voltage harmonic distortion in the system can be seen in the table 2.

Bus Voltage (V) At PCC	Individual Harmonic (%)	Total Harmonic Distortion (%)
V ≤ 1KV	5.0	8.0
1KV < V < 69KV	3.0	5.0
69KV < V < 161KV	1.5	2.5
161KV < V	1.0	1.5

Table 2. IEEE 519-2014

Analysis based on IEEE 519-2014

THD based on IEEE 519-2014 is known that the standard V THD with the nominal voltage between 1KV and 69KV is 5%. V THD analysis result can be seen in the table:

Voltage	Simulation VTHD (%)	Standard VTHD (%)	Remark
1KV< V< 69KV	0.14 %	5%	Appropriate

Table 3. Analysis VTHD Based on IEEE 519-2014

Orde	Power IN (W)	Power Out (W)	Losess (W)	Efisiensi	RPM	TORSI
0	54705,1	38798,9	15906,2	70,92%	1493,9	307,7
1	59499,8	41777,4	17722,5	70,21%	1495,0	308,1
2	55518,1	39496,9	16021,1	71,14%	1493,7	308,8
3	54705,1	38798,9	15906,2	70,92%	1493,9	307,7
4	54821,1	38987,5	15833,6	71,12%	1493,8	307,2
5	54894,3	38989,5	15904,8	71,03%	1493,8	307,9
6	54705,1	38798,9	15906,2	70,92%	1493,9	307,7
7	54807,3	38927,4	15880,0	71,03%	1493,8	307,6
8	54810,3	38910,8	15899,5	70,99%	1493,9	307,6
9	54705,1	38798,9	15906,2	70,92%	1493,9	307,7

Table 4. Simulation Result

Analysis of Losses and Efficiency

Losses in this simulation are influence from Pin and Pout data. The knowing data is

Pin = 59499,8

Pout = 41777,4

Losses = Pin – Pout

= 59499.8 – 41777.4

= 17722.4 W = 17.7KW

Efficiency $= \frac{\text{Pout}}{\text{Pin}} \times 100\%$

$= \frac{\text{Pout}}{\text{Pout+Losses}} \times 100\%$

$= \frac{41777.4}{41777.4 + 17722.4} \times 100\%$

$= \frac{41777.4}{59499.8} \times 100\%$

= 70,21%

4. CLOSING

Based on the result analysis in Simulink Matlab about the effect of total harmonic distortion to losses and efficiency of three phase induction motor, the following result are obtained:

The result of harmonic distortion in the motor circuit, the losses of motor with harmonic is higher that without harmonic distortion. Based on the calculation, the efficiency is lower than without harmonic. It also influence the value of RPM and Torque of motor. Therefore, the harmonic distortion is influence the value of losses, efficiency, RPM, and Torque of motor. If the value of losses is low, so the value of efficiency is high and vice versa.

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