Fault Detection and Analysis of Three-Phase Induction Motors using MATLAB Simulink Model

Akshay A. Umap[1], Chetan M. Bobade[2]

[1]PG Scholar, Electrical Engineering Department, G.H.Raisoni College of Engineering, Amravati
[2]Head of Department, Electrical Engineering Department, G.H.Raisoni College of Engineering, Amravati
Maharashtra, India

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Abstract - *Induction motors area unit important elements in several industrial processes. In spite of their hardiness they are doing sometimes fail and their ensuing unplanned period will prove terribly pricey. Therefore, condition watching of electrical machines has received hefty attention in recent years. There are a unit many ways to find mechanical and electrical issues in induction motors, either directly or indirectly. Directly, several parameters are often monitored to supply helpful indications of inchoate faults. These parameters embrace case vibration and noise, mechanical device part current, air-gap or external magnetic compactness.*

For analysis of fault condition typical methodology of fast Fourier remodel unit of measurement initial use and take a glance at for varied winding fault conditions. Then symbolic logic controller supported fuzzy rule base vogue for analysis of mechanical device winding faults. From every the conditions it clear that the FFT analysis entirely calibrate total harmonics distortion (THD) of faulted voltage and current signal of three section induction motor input aspect (stator side).

Whereas Fuzzy logic controller directly analyzed the kind of the fault on induction motor mechanical device winding. Motor model and fault analysis system vogue in MATLAB 2015 Simulink coding system. Victimization this coding system, motor parameter analysis, fault cases analyzed.

Key Words: Induction motor fault analysis, fuzzy logic control

1. INTRODUCTION

Induction motors (IM) square measure utilized in several industrial applications to convert power into mechanical, due its high potency, robustness, responsibility and low maintenance prices. IM square measure wide used, aiming to consume among four-hundredth to five hundredth of all energy capability generated in an exceedingly industrial country [1].

IM gift faults, occurs due to many reasons like aging, installation conditions, inadequate applications, lack of preventive maintenance and mechanical or electrical stress [2] [3]. The additional common faults, as listed in [3] and [4], occur within the mechanical device winding, the insulation of the mechanical device or rotor, through the gap bars, crack rings or dynamic and static eccentricity.

As indicated in [5] and [6], the short between winding turns is that the second most typical explanation for fault in IM. Once the IM square measure driven by frequency device (inverter), matters tends to be even worse owing to the strain obligatory by the quick voltage transitions obligatory by the inverter's transistors that contributes even additional to the insulation breakdown [7]. In [8] is indicated that the strain within the winding is 10 times worse on machines high-powered by the inverters.

In this state of affairs, there's a trend within the trade and analysis community to develop solutions to discover faults in IM as indicated in reviews like [3] and [7]. Also, with the impact of frequency converters, arises the likelihood of preventive medicine by non-invasive techniques through constant on-line observance. If associate degree formula to diagnosing the condition of the motor is evolved to be embedded in an exceedingly microcontroller, as an example, it's attainable to embedded this formula within the frequency device controller, taking advantage of the hardware gift in most of this sort of kit. Some researches indicates that this diagnosing is done mistreatment AI algorithms as seen in works like [9]-[11] and printed works by the authors [12]-[15].

2. PROPOSED APPROACH

2.1. FFT Analysis of IM

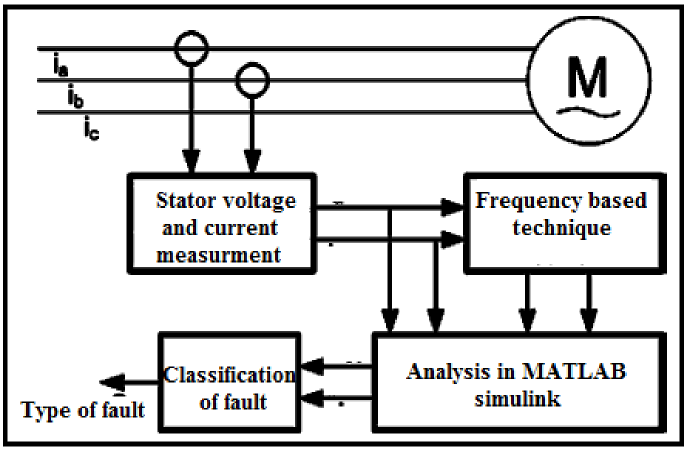

Fig -1: Generalized block diagram of FFT analysis

Figure 1 shows the FFT approach for three-phase induction motor analysis or harmonics analysis. In these approaches initial three-phase induction motor input voltage and input current are measured victimization CTs and PTs. Then measures RMS three-phase voltage and current signal send to FFT analysis blocks. During this section total harmonics content was analyzed for traditional conditions and conjointly for abnormal winding faults conditions. By observant the harmonics contents in traditional condition and abnormally we have a tendency to analyzed the entire Harmonics distortion (THD) of every 3-phase voltage and three phases current. From the analysis, it's clear that harmonics content throughout traditional conditions is minimum for each three-phase voltage and three-phase current signals. However this condition true just for a number of fault condition doesn't satisfy all conditions. to spot all winding faults condition of three-phase induction motor.

2.2. Fuzzy Logic Controller Approach of IM

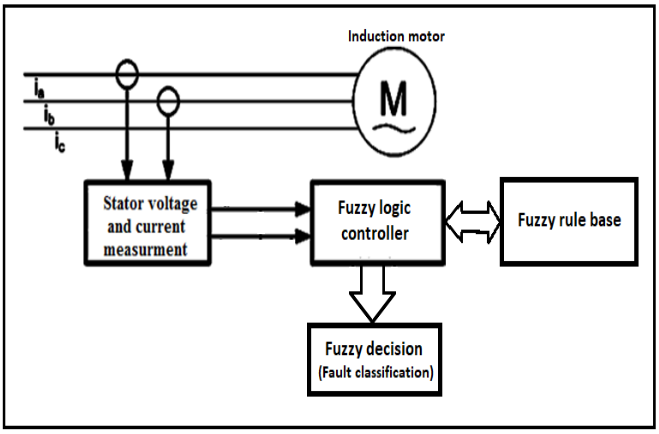

Fig-2: Generalized block diagram of fuzzy logic controller based approach

Figure 2 of shows the fuzzy logic controller primarily based three-phase induction motor fault classification. In these approaches 1st three-phase induction motor input voltage and input current square measure measured exploitation CTs and PTs. Fuzzy rule base for a fuzzy logic controller system, for that purpose three-phase induction motor, operate the conventional condition and totally different fault conditions. supported a reading of three-phase voltage and current, rules square measure designed for traditional, part to part winding fault, part to a ground winding fault and contact fault. Then when formal logic controller places when the three-phase voltage and current measure system.

3. MATLAB Simulation model

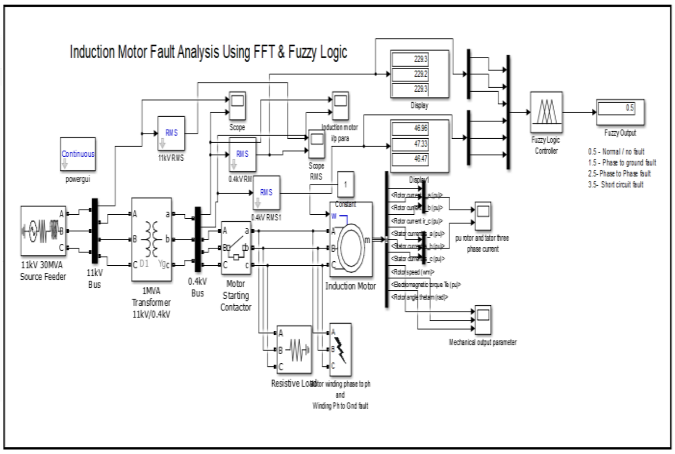

Fig-3: MATLAB simulation model of proposed approach

Table-1: MATLAB simulink model parameter specifications

Sr No	Name of simulation block	Parameter specification
1	11KV, 30MVA, Source feeder	Phase to phase RMS voltage = 11 KV; Frequency = 50Hz; Three phase short circuit level at base voltage = 30 MVA; Base voltage = 11 KV; X/R Ratio =7
2	1 MVA Transformer	Primary winding connection = Delta; Secondary winding connection = Star with earth grounded; Nominal power = 1 MVA; Frequency =50Hz; Primary winding voltage = 11KV; Secondary winding voltage = 0.4 KV; Primary and secondary winding resistance = 0.002 Pu; Primary and secondary winding inductance = 0.08 pu; Magnetizing resistance and inductance = 500pu
3	Motor starting contractor	Initial status of breaker = open; Switching time = 0.1 Sec; Breaker resistance Ron = 0.001 Ohm; Snubber resistance = 1 Mega Ohm
4	Induction motor	Rotor type = Squirrel cage; motor model: 100HP; Power =75 KW; V =400V; speed = 1484 RPM; Nominal power = 75 KVA; Vn = 400 V; Frequency =50Hz; Stator resistance = 0.01665 pu; Stator inductance = 0.04955pu; Rotor resistance Rr = 0.009805pu; Rotor inductance Rl = 0.04988pu; Mutual inductance Lm = 2.224pu; Pole pair = 2

4. MATLAB SIMULATION RESULTS

4.1. Results from FFT analysis

Table-2: FFT Analysis result for calibration of Total Harmonics Distortion (THD)

Sr No	Fault type	Total Harmonics Distortion (THD) %					
		Va	Vb	Vc	Ia	Ib	Ic
1	Normal	1.7	1.93	1.55	84.72	93.91	84.81
2	Ph-Gnd (A-G)	53.21	2.06	2.17	64.02	101..97	48.43
3	Ph-Gnd (B-G)	2.37	55.47	1.7	51.29	66.43	90.55
4	Ph-Gnd (C-G)	1.78	2.51	50.75	91.9	51.08	68.02
5	Ph-Ph (A-B)	46.68	49.31	2.14	63.81	63.56	48.99
6	Ph-Ph (B-C)	2.23	46.69	48.95	46.57	66.06	66.28
7	Ph-Ph (A-C)	45.34	2.445	43.1	65.59	48.02	66.15
8	Three phase short circuit	68.32	73.65	68.17	64.38	64.55	66.8

Table 1 shows the Total harmonics distortion calibration using FFT analysis. From above table it is clear that during normal condition of three phase induction motor THD for three phase voltage is below 2% and three phase current THD is in between 80 to 95%. For abnormal condition total harmonics distortion for faulted phases was increases that means harmonics content increases in faulted phase.

4.1.1. Normal condition

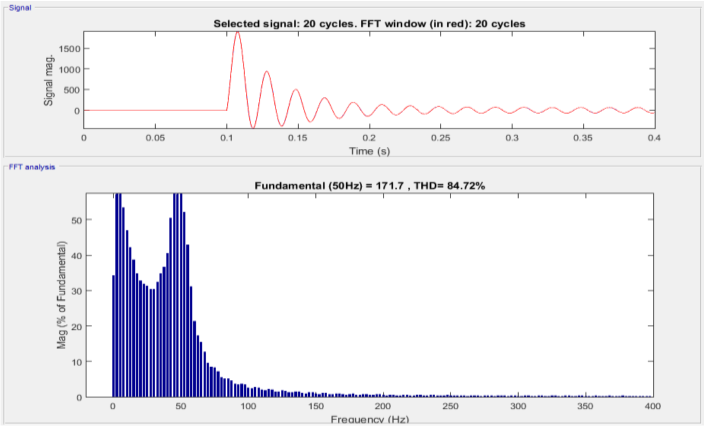

Fig-4: FFT Analysis on phase A current signal during normal condition

Figure 4 shows the FFT analysis window for phase A current of induction motor input supply during normal operation condition in which it observed that Total harmonics distortion (THD) is minimum due to presence of less amount of harmonics content due to faults or harmonics absents in current. The THD is calibrated for phase A current during normal condition is around 84.72%.

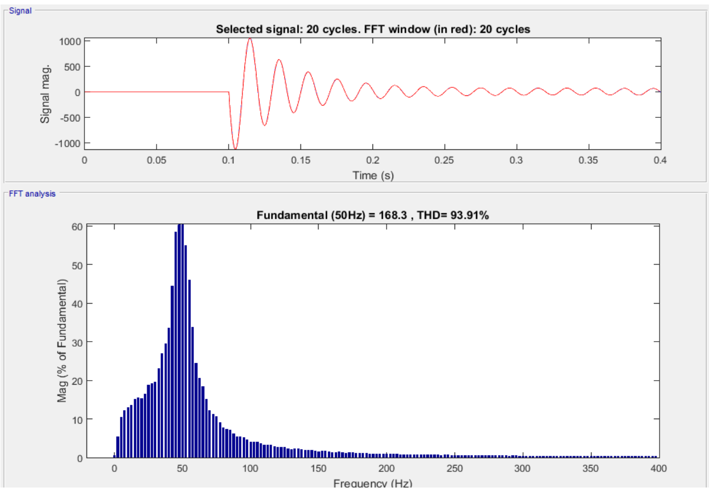

Fig-5: FFT Analysis on phase B current signal during normal condition

Figure 5 shows the FFT analysis window for phase B current of induction motor input supply during normal operation condition in which it observed that Total harmonics distortion (THD) is minimum due to presence of less amount of harmonics content due to faults or harmonics absents in current. The THD is calibrated for phase B current during normal condition is around 93.91%.

4.1.2. Phase to ground winding fault

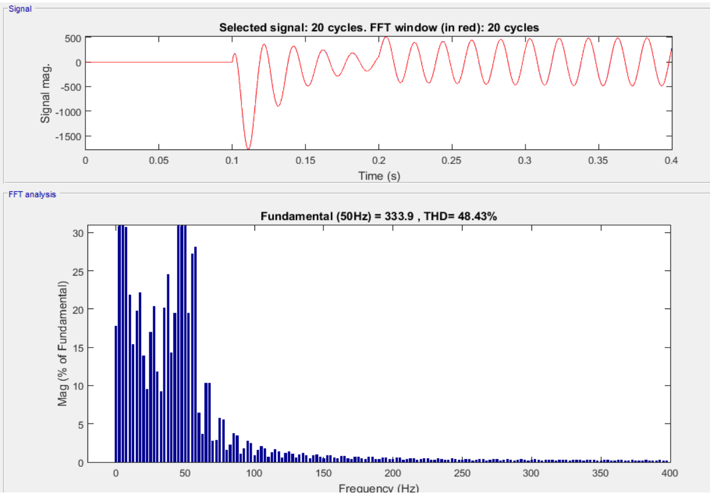

Fig-6: FFT Analysis on phase A current of induction motor during phase to ground fault in phase A winding to Ground

Figure 6 shows the FFT analysis window for phase A current of induction motor input supply during phase to ground fault in phase A winding to Ground in which it observed that Total harmonics distortion (THD) is minimum due to magnitude of current in phase A increases due to ground fault. The THD is calibrated for phase A current during phase to ground fault in phase A winding to Ground is around 48.43%.

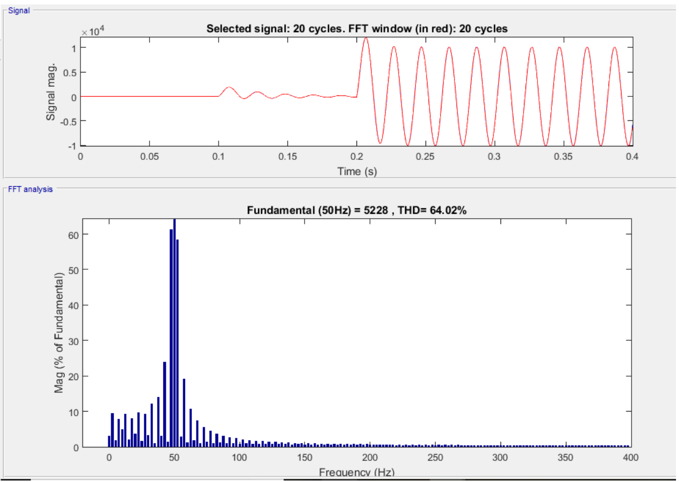

Fig-7: FFT Analysis on phase C current of induction motor during phase to ground fault in phase A winding to Ground

Figure 7 shows the FFT analysis window for phase C current of induction motor input supply during phase to ground fault in phase C winding to Ground in which it observed that Total harmonics distortion (THD) is around 64.02%.

4.1.3. Phase to phase winding fault

Figure 8 shows the FFT analysis window for phase C voltage of induction motor input supply during phase to Phase fault in phase A winding to C Winding in which it observed that Total harmonics distortion (THD) is around 77.49%.

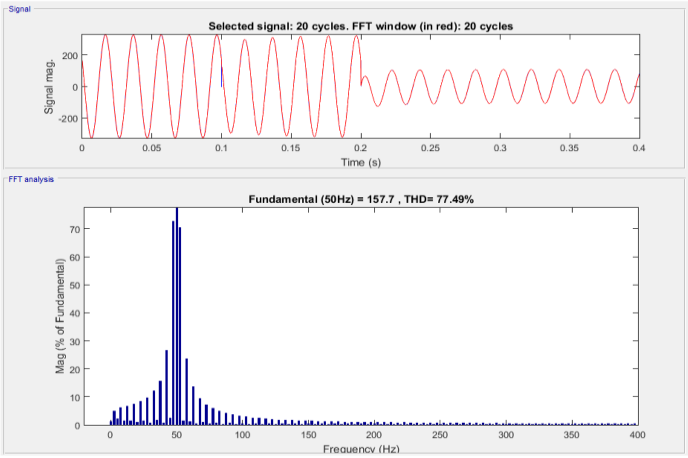

Fig-8: FFT Analysis on phase C Voltage of induction motor during phase to Phase fault in phase A winding to C Winding

Figure 9 shows the FFT analysis window for phase A voltage of induction motor input supply during phase to Phase fault in phase A winding to C Winding in which it observed that Total harmonics distortion (THD) is around 39.53%.

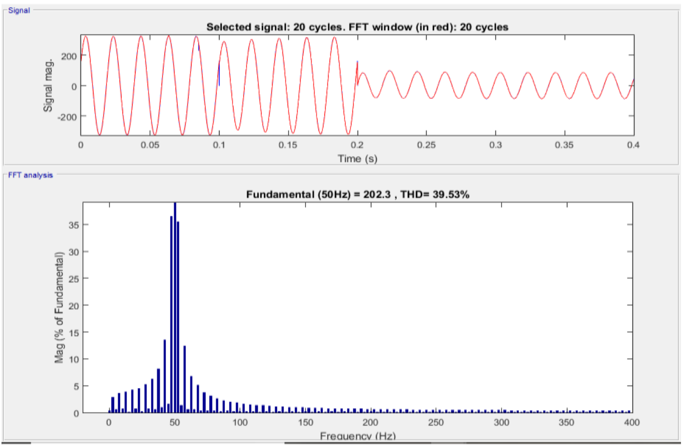

Fig-9: FFT Analysis on phase A voltage of induction motor during phase to Phase fault in phase A winding to C Winding

4.1.4. Three Phase Short Circuit Winding Fault

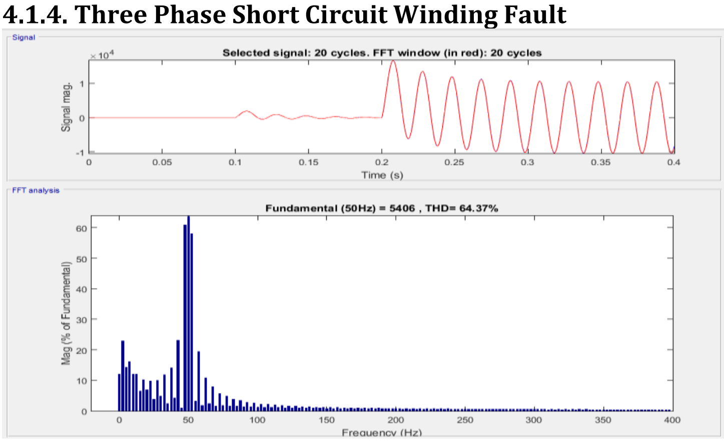

Fig-10: FFT Analysis on phase A Current of induction motor during three phase short circuit in stator winding

Figure 10 shows the FFT analysis window for phase A current of induction motor input supply during three phase short circuit in stator winding in which it observed that Total harmonics distortion (THD) is around 64.37%.

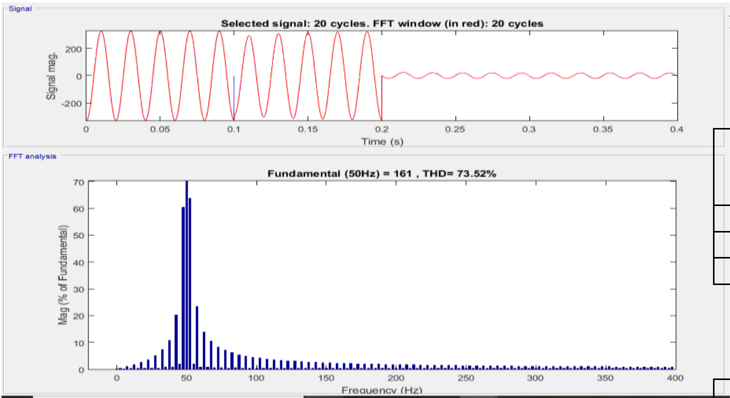

Fig-11: FFT Analysis on phase B Voltage of induction motor during three phase short circuit in stator winding

Figure 11 shows the FFT analysis window for phase B Voltage of induction motor input supply during three phase short circuit in stator winding in which it observed that Total harmonics distortion (THD) is around 73.52%.

Figure 4 to 11shows the FFT window for calibration of total harmonics distortion (THD) for normal and abnormal faults conditions on three phase induction motor.

4.2. Results from Fuzzy Logic Control

4.2.1. Fuzzy Logic controller

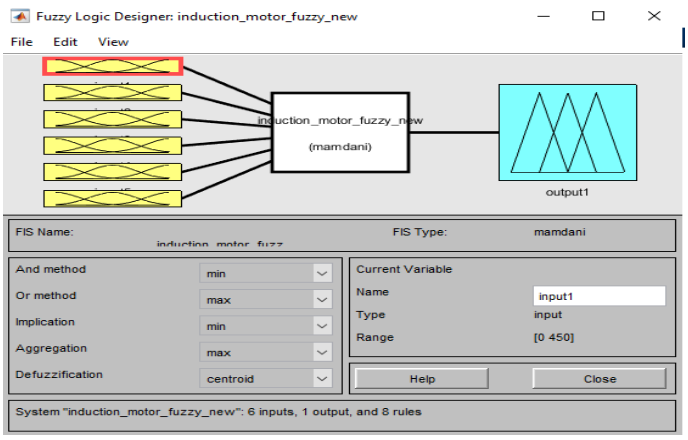

Fig-12: Fuzzy logic controller designing toolbox in MATLAB simulink for induction motor fault analysis

Figure 12 shows the fuzzy logic controller toolbox window in matlab simulink 2015 version. In which we have to design input membership function that means three phase voltages of induction motor Va, Vb, Vc as well as three phase input current Ia, Ib, Ic. Also output membership design for classification of different faults classifications like membership functions for Phase to ground, Winding phase to phase fault and Winding short circuit faults. The membership functions design for all inputs and outputs are triangular membership function. The range of input voltage A membership function shown in table 3. The range of input Current phase C membership function shown in table 4. The range of output i.e. types of induction motor faults membership function shown in table 5.

Table-3: Rang of membership function input phase A voltage

Name of Membership function (MF)	Range	Type of MF
Low	0 to 50 to 100	Triangular
Medium	100 to 150 to 200	Triangular
High	200 to 325 to 450	Triangular

Table-4: Rang of membership function input phase C current

Name of Membership function (MF)	Range	Type of MF
Low	0 to 25 to 50	Triangular
Medium	50 to 1838 to 3725	Triangular
High	3725 to 5615 to 7500	Triangular

Table-5: Rang of membership function output types of IM faults classification

Name of Membership function (MF)	Range	Type of MF
Normal condition	0 to 0.5 to 1	Triangular
Phase to ground fault	1 to 1.5 to 2	Triangular
Phase to phase fault	2 to 2.5 to 3	Triangular
Short circuit wdg fault	3 to 3.5 to 4	Triangular

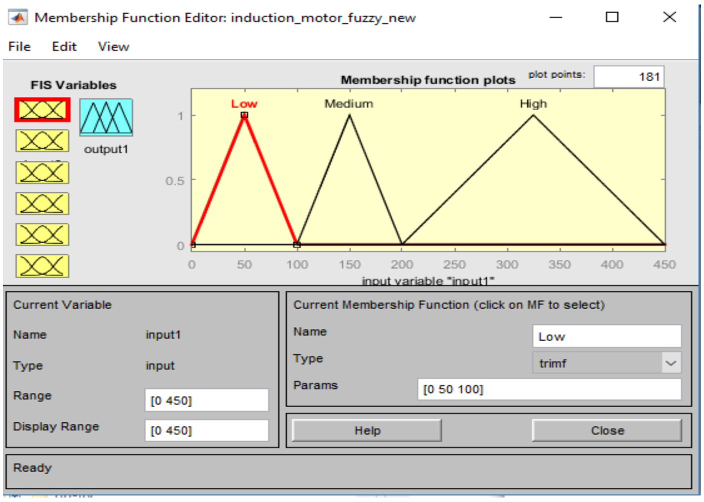

Fig-13: Membership function for three phase A stator input voltage

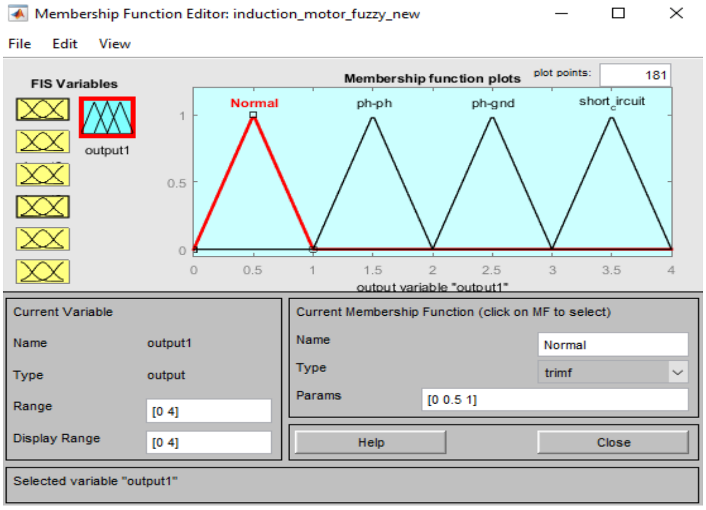

Fig-14: Membership function for fuzzy decision for three phase induction motor fault classification

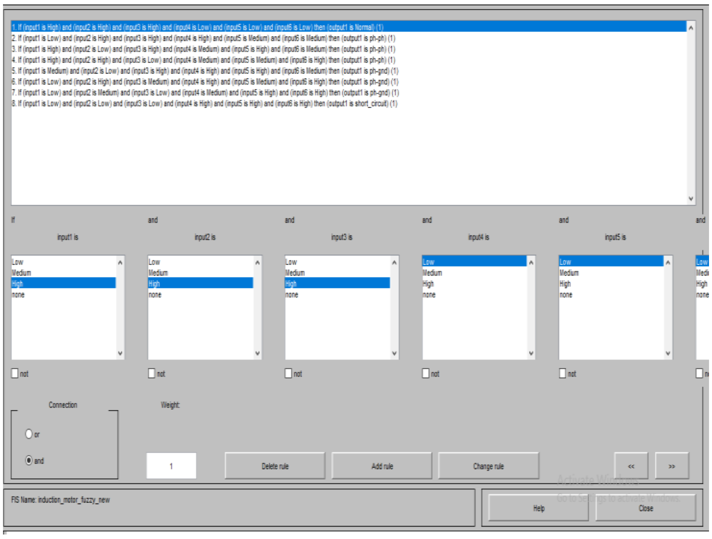

Fig-15: Fuzzy rule base for fuzzy logic controller

Figure 15 shows the fuzzy logic controller rule base design window, in which window we have to design rule base for fuzzy logic controller based on available input ranges. The rule base design is totally depends upon system parameter behaviors. Fuzzy "if then" Rules designs in that window are shown in table 7 in short form manner.

Table-6: Three phase stator current and voltage for different fault condition and normal condition

Sr No	Faults	Fault Type	Va	Vb	Vc	Ia	Ib	Ic
1	Normal	Normal	229.4	229.4	229.4	47.51	47.48	47.52
2	AG	Wgd ph-Gn	89.24	220	218.7	7174	313.3	345.1
3	BG	Wgd ph-Gn	218.8	89.24	220	345.2	7174	313.3
4	CG	Wgd ph-Gn	220	218.7	89.24	313.5	345.1	7174
5	AB	Wdg ph-ph	120.8	94.51	215.3	6459	6396	521.8
6	BC	Wdg ph-ph	215.2	120.8	94.5	522	6457	6393
7	AC	Wdg ph-ph	94.47	215.2	120.7	6395	522.1	6458
8	ABC	Wdg ph-ph	14.83	14.81	14.79	7410	7403	7399
9	ABCG	Wgd ph-Gn	14.83	14.8	14.8	7412	7402	7397

Table 6 shows the input three phase voltages and currents of three phase induction motor which measures at normal conditions as well as during abnormal condition or fault conditions.

Table-7: Fuzzy Rule and corresponding fuzzy decision

Sr No	Va	Vb	Vc	Ia	Ib	Ic	ph-ph	ph-gnd	short circuit	normal
1	H	H	H	L	L	L	0	0	0	1
2	L	H	H	H	M	M	2	0	0	0
3	H	L	H	M	H	M	2	0	0	0
4	H	H	L	M	M	H	2	0	0	0
5	M	L	H	H	H	M	0	3	0	0
6	L	H	M	H	M	H	0	3	0	0
7	L	M	L	M	H	H	0	3	0	0
8	L	L	L	H	H	H	0	0	4	0

Note : H = High = Range for voltage (0 to 100 Volts) and for current (0 to 50 Amperes)
M = Medium = Range for voltage (100 to 200 Volts) and for current (50 to 3725 Amperes)
L = Low = Range for voltage (200 to 450 Volts) and for current (3725 to 7500 Amperes)

4.3. Result for three phase induction motor

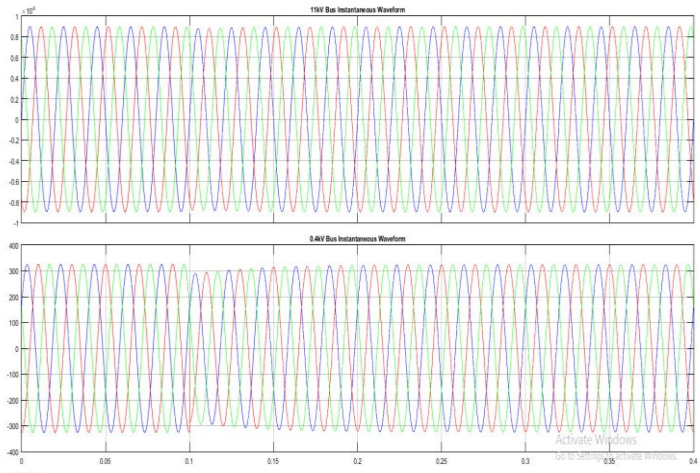

Fig-16: Three phase induction motor input three phase voltage and current

Figure 16 shows the three phase input voltage and currents of induction motor during normal condition. It observed that three phase voltage and current measured are at rated values. Similarly, figure 17 shows the RMS values of three phase input voltage and current of three phase induction motor during normal operation conditions.

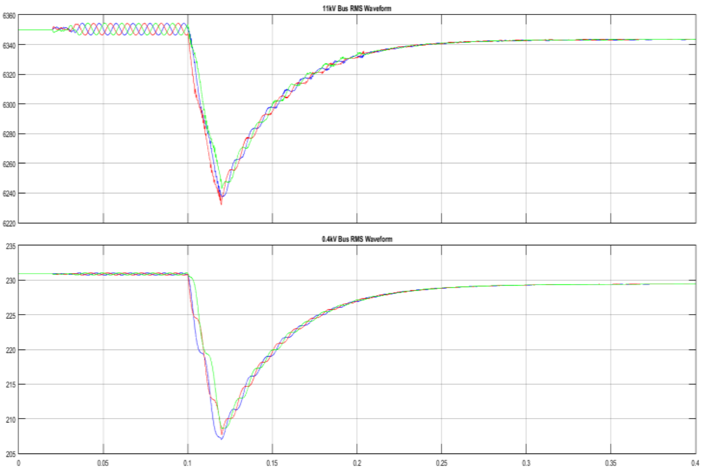

Fig-17: Three phase RMS 11kv bus bar voltage and 0.4KV RMS bus bar voltage

Table 7 shows the comparative analysis between FFT analysis and Fuzzy logic controller analysis for induction motor fault classifications. It observed that fuzzy logic approach is more superior, fast as compared with FFT analysis approach.

Table-7: Comparison of FFT and Fuzzy Logic control technique

Sr No	FFT Analysis	Fuzzy Logic control Technique
1	FFT analyzed frequency components of input voltage and current of stator.	Not analyzed frequency of three phase stator voltage and current
2	Not classify type of fault occurs in machine	Exactly classify each type of fault in three phase induction motor
3	Time required for analysis is more	Time require for classification in very less.
4	Complex analysis	Easy analysis
5	Not generalization for different machines	Generalization of rule base system design for any machine protection

5. CONCLUSION

FFT analysis only analyzed total harmonics distortion of stator input voltage and current. FFT Analysis takes more time for analysis of fault condition. It requires to analyze each phase voltage and current THD.

Fuzzy logic controller rule base system easily classifies each type of three phase induction motor fault conditions. Fuzzy logic controllers classify the fault with the short duration of time as compared with FFT analysis technique. Efficiency of fuzzy logic controller as compared with FFT analysis for three phase induction motor fault classification is more.

As a possible extension to this work, it would be quite useful to analyze all fault conditions for synchronous machine. Also extend for DC motor drive fault analysis and Brushless DC motor drive fault classification.

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