Neutrosophic Inference System (NIS) in Power Electrical Transformers, Adapted the MIL-STD-1629A

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Abstract:

This study is concerned with creating a neutrosophic inference system (NIS) and developing its mathematical concepts, as well as determining the most critical problems in the power electrical transformers. Studying their potential failure mode and effects analysis and then, analyzing the risk assessment and management. New insight and novel techniques have been presented to interpret the failure modes (i.e. severity, occurrence, and detection). This paper presents a novel operator called ANOR which is used for the first time to combine the (IF-Then) inference rules. The neutrosophic inference system using failure mode effect analysis is a modern tool for studying the reliability of electrical power transformers. Also, this study suggested some modifications in the standard MIL-STD-1629A. this article presents and for the first time, a new inferencing sixty-three neutrosophic rules in which their biasing is categorized into three types: truth state, indeterminacy state, and falsity state.

Keywords: Neutrosophic Failure Mode Effect Analysis (NFMEA); Neutrosophic Risk Priority Number (NRPN); Neutrosophic Inference Analysis NFMEA; type -1- Mamdani inference system; MIL-STD-1629A.

1. Introduction

It is well-known that all inference systems techniques such as the type-1 and type-2 Mamdani system and type-1 and type-2 Sugeno system were created in the 1970s. In 1975, Prof. E. Mamdani built one of the first fuzzy systems to control a steam engine and boiler combination, it is still implemented in fuzzy environments as an active tool for analyzing fuzzy control systems, we can define the fuzzy controllers simply as it came in literature, they are very simple conceptually because they are composed of input, processing, and output stages. As a special case, if we focused on the electrical power transformer for the reasons that:

1- The power transformers have an active role in the efficiency and reliability of power transmission lines,

2- The electrical power transformer is one of the most expensive network equipment.

3- It is important to know when the electrical power transformer facing danger because it contains a great quantity of oil in contact with high-voltage elements.

Therefore, the objective is to study the failure modes and their effect analysis for it by giving up the well-known fuzzy approach and replacing it with a neutrosophic inference system (NIS). Before moving forward with this new approach (i.e. putting the mathematical fundamentals of NIS), some of the basic concepts are present in the upcoming sections. Till this moment and before this study, the traditional and fuzzy methods are being taken up to analyze the parameters, and criteria which increase the risk of fire and explosion in case of abnormal circumstances or technical failures using the traditional and fuzzy control systems with the general goal of improving the reliability of the system. Many researchers published dozens of articles in this field including but not limited to [1-6].

To describe the use of potential failure mode and effects analysis in the neutrosophic environments (NFMEA), we need to determine the inputs of the neutrosophic inference system (NIS) that will be the mathematical tool for risk assessment and management, the inputs of the NIS in the electrical power transformers (EPT) that have been considered in this paper are [7-10]:

1- Active Part which consists of the Core (i.e. having the function of concentrating the magnetic flux), the Windings (i.e. the function of the windings is to carry current. In addition to dielectric stress and thermal requirements the windings have to withstand mechanical forces that may cause windings replacement).

2- Insulation system which consists of the solid insulation and the transformer oil.

3- Some transformer components which is known as accessories are Bushings, Tap Changer, cooling system, Tank, Mechanical structure includes (clamping, coil blocking and lead support), and Winding Connections that are between windings, tap leads, and to bushings).

4- Protection which includes the Buchholz protection, pressure relief, valve circuity, sure protection, and tap changer pressure relief.

At the experts, these parts are well known, it should be studied the severity, occurrence, and detection of each problem caused in one of the previously mentioned parts of (EPT). Again, the neutrosophic inference system (NIS) consists of an input stage, a processing stage, and an output stage, the processing stage invokes each appropriate rule and generates results for each rule, then combines the results of the rules. The output stage converts the combined result back into a specific control output value.

The membership functions that should be used in the neutrosophic inference system, and how to classify the (If-then), (If- and- then), (If-or-then), and (If- anor-then) statements will be discussed with details in the forthcoming sections.

2. A Comparison Between Conventional FMEA, Fuzzy FMEA and Neutrosophic FMEA

NASA agency in 1963 adopted the FMEA as a formal system analysis methodology for their reliability requirements. Then, it was adopted and implemented by Ford Motor in 1977 [8] simultaneously with the military standard procedures for performing a failure mode, effects, and critical analysis which has been released by the USA Department of Defense on June 12, 1977. Since then, it has become a powerful tool extensively used for risk and reliability analysis of systems in a wide range of industries, including automotive, construction, aerospace, nuclear, and electro-technical [5].

Reliability and quality assurance have been of increasing concern in various industries in recent years. The evidence of this argumentation is that there are many different standards developed for failure modes and effects analysis (FMEA) application in various industries, and the most popular standards are:

- SAE-J-1739 [state ref.], /great for the ground vehicle community.
- AIAG's [state ref.], /a reference manual to be used by suppliers to Chrysler LLC, Ford Motor Company, and General Motors Corporation.
- MIL-STD-1629A [state ref.] / drafted by the United States Department of Defense.
- IEC 60812 [state ref.] / guidance to how these techniques may be applied to achieve various reliability program objectives.
- BSEN 60812 [state ref.]/ the European adoption of the IEC 60812.

The above standards are dedicated for conventional FME, a typical standard will outline Severity, Occurrence, and Detection rating scales as well as examples of an FMEA spreadsheet layout. Also, a glossary will be included that defines all terms used in the FMEA. The rating scales and the layout of the data can be different between standards, but the processes and definitions remain similar. However, in general, FMEA is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures, in order to identify the parts of the process that are must in need of repair and maintenance [2].

Even though the conventional FMEA is probably the most popular tool for reliability and failure mode analysis in electrical power transformers, there are some limitations in it since it is difficult or even impossible for experts to precisely evaluate the three risk factors S, O, and D, since the risk factors are often expressed in a linguistic way (such as 'likely', 'important', 'very high', 'catastrophic', 'marginal', 'minor'…etc.). as well as, in traditional FMEA methodology, the three risk factors are assumed to have the same importance [11-16]. However, it is observed that many operative and management experts give more preference to the "fault detection factor".

The neutrosophic failure mode effect analysis (NFMEA) is proposed in this study, which will be more general in its aspects than the fuzzy failure mode effect analysis (FFMEA) since the latter concentrates on the creation of membership functions for the antecedents and consequences of rules, while the (NFMEA) is more accurate in classifying the cases of Severity into three main portions (membership function supports the Truth Side/ MFT, membership function supports the Indeterminate Side/ MFI, and membership function supports the Falsity Side/ MFF), same talking goes for Occurrence and Detections. In this manner, the membership functions that were used in FFMEA will be hugely different from what they will be used in NFMEA. In this study we adopt the strategy that the relations between MFT, MFI, and MFF are simply represented as:

$$MFF = 1 - MFT, MFI = MFT \cap \text{MFF} \; \ldots\ldots\ldots\ldots\ldots\ldots . (1)$$

It means from a philosophical point of view that the behavior of the truth membership function for any neutrosophic object (i.e. number, element, variable, function…etc.) has the inverse behavior of the falsity membership function for the same object, while the indeterminacy membership function for that object is exactly the intersection of the two membership functions MFT and MFF because the indeterminacy case is neither truth nor false but it is swinging between them this means the indeterminacy may contain some truth combined with some falsity. The following mathematical definition is a great representation of the severity criteria, Occurrence criteria, and Detection criteria that would be used to formulate the rules in NFMEA.

2.1 Definition [7]

Let A_0 be the set of all neutrosophic non-liner functions $g(x)$ that are neutrosophically less than or equal to z, i.e. $A_0 = \{x_i \in FN_m,\ g(x) < ₦\, z\}$. The membership functions of $g(x)$ and $anti(g(x))$ are:

$$\mu_{A_o}\big(g(x)\big) = \begin{cases} 1 & 0 \le g(x) \le z \\ \left(e^{\frac{-1}{d_o}(g(x)-z)} + e^{\frac{-1}{d_o}(anti\ (g(x))-z)} - 1\right), & z < g(x) \le z - d_o \ln 0.5 \end{cases} \quad (2)$$

$$\mu_{A_o}(anti(\ g(x))) = \begin{cases} 0 & 0 \le g(x) \le z \\ \left(1 - e^{\frac{-1}{d_o}(anti\ (g(x))-z)} - e^{\frac{-1}{d_o}(g(x)-z)}\right), & z - d_o \ln 0.5 \le g(x) \le z + d_o \end{cases} \quad (3)$$

It is clear that $\mu_{A_o}(neut(\ g(x)))$ consists from the intersection of the following functions:

$$e^{\frac{-1}{d_o}(g(x)-z)} \quad \&\ 1 - e^{\frac{-1}{d_o}(anti(g(x))-z)} \quad (4)$$

$$\mu_{A_o}(neut(\ g(x))) = \begin{cases} 1 - e^{\frac{-1}{d_o}(anti(\ g(x))-z)} & z \le g(x) \le z - d_o \ln 0.5 \\ e^{\frac{-1}{d_o}(g(x)-z)} & z - d_o \ln 0.5 < g(x) \le z + d_o \end{cases} \quad (5)$$

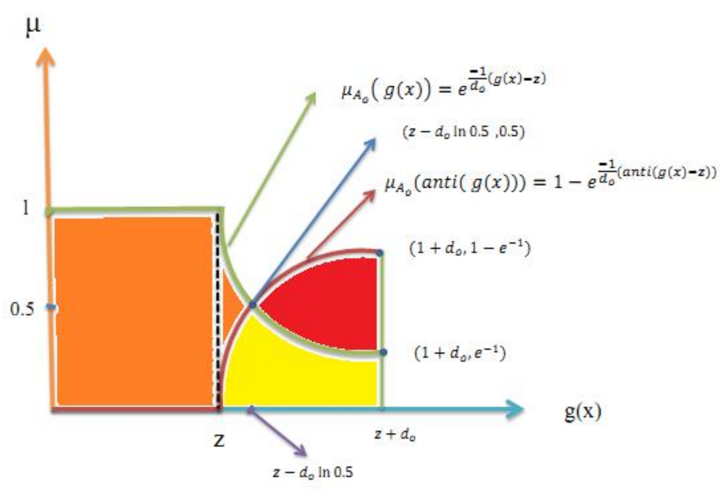


Figure 1.1: The orange color means the region covered by $\mu_{A_o}\big(g(x)\big)$, the red color means the region covered by $\mu_{A_o}(anti(\ g(x)))$, and the yellow color means the region covered by $\mu_{A_o}(neut(\ g(x)))$.

3. The construction of Rules in the Neutrosophic Inference Systems

It is an important issue to talk about the IF-Then statements in fuzzy rule sets before presenting our modification on these fuzzy rules to transfer it from fuzzy environments to neutrosophic environments.

We mentioned in the introduction section, one of the stages in any inference system is the processing stage which consists of a collection of logic rules in the frame of IF_THEN phrases. However, the IF-portion is called the antecedent, while the THEN-portion is called the consequent. Regular fuzzy control systems have dozens of rules.

Consider a rule for the severity input in the electrical power transformer:

IF (the primary function can be done) and (urgent repair is required) THEN (the risk severity on the power transformer is minor)

The above fuzzy inference rules no longer meet the need, more sophisticated rules should be formulated from the neutrosophic perspective.

Moreover, the fuzzy operators (AND, OR, NOT) that combines several antecedents should be extended to include new operator.

3.1 Creation of the Neutrosophic Inference Rules

The truth, indeterminacy, and falsity for neutrosophic terms such as (about, near, close to, approximately, very slightly, too, extremely, somewhat) have spectrums of severity due to the definitions can vary considerably among different implementations.

The following three tables illustrate neutrosophic rules in which the neutrosophic inference systems can be in new apparel:

Table (1): Neutrosophic Rules for Severity Inputs of the Power Transformer

Truth	IF the primary function can be done AND un-urgent repair is required THEN the risk severity on the power transformer is minor-minor
Indeterminacy	IF the primary function can be done AND urgent repair is required THEN the risk severity on the power transformer is rather-minor
Falsity	IF the primary function can be done AND very-urgent repair is required THEN the risk severity on the power transformer is minor
Truth	IF there is a few reduction in the ability to implement the primary function THEN the risk severity on the power transformer is a mini-marginal.
Indeterminacy	IF there is a normal reduction in the ability to implement the primary function THEN the risk severity on the power transformer is a rather-marginal.
Falsity	IF there is an extremely reduction in the ability to implement the primary function THEN the risk severity on the power transformer is a marginal.
Truth	IF the problem does not cause a loss of primary function THEN the state of the system is not critical
Indeterminacy	IF the problem causes a partial loss of primary function THEN the state of the system is rather critical
Falsity	IF the problem causes a totally loss of primary function THEN the state of the system is critical
Truth	IF the system becomes partially inoperative THEN the state is not catastrophic
Indeterminacy	IF the system becomes inoperative THEN the state is rather catastrophic
Falsity	IF the system becomes completely inoperative THEN the state completely catastrophic

Table (2): Neutrosophic Rules for Occurrence Inputs of the Power Transformer

Truth1	IF a single failure mode probability of occurrence is less than 0.001 THEN the probability of the risk occurrence on the power transformer is extremely unlikely.
Truth2	IF a single failure mode probability of occurrence is less than 0.01 THEN the probability of the risk occurrence on the power transformer is unlikely.
Indeterminate1	IF a single failure mode probability of occurrence is less than 0.1 THEN the probability of the risk occurrence on the power transformer is occasional.

Indeterminate2	IF a single failure mode probability of occurrence is less than 0.2 THEN the probability of the risk occurrence on the power transformer is reasonably probable.
Falsity1	IF a single failure mode probability of occurrence is greater than 0.2 THEN the probability of the risk occurrence on the power transformer is sometimes frequent.
Falsity2	IF a single failure mode probability of occurrence is greater than 0.3 THEN the probability of the risk occurrence on the power transformer is permanently frequent.

Table (3): Neutrosophic Rules for Detection Inputs of the Power Transformer

Truth1	IF the problem has been well identified THEN the problem will be completely fixed before the electricity services reach to the customer.
Truth2	IF the problem has been fairly identified THEN the problem will be fixed before the electricity services reach to the customer.
Indeterminate1	IF the problem has been well detected AND rough identification THEN the problem will be nearly fixed before the electricity services reach to the customer.
Indeterminate2	IF the problem has been fairly detected THEN the problem will cause a delay in reaching the electricity services to the customer.
Falsity1	IF the problem has been roughly detected THEN the problem will cause a temporary pause in the system.
Falsity2	IF the system needs to complementary test THEN the problem will cause a pause in the system.

Regarded table (3), it is worth mentioning that the term ''identification'' indicates that the source or the location of the defect or the fault has been determined by the test. while the term "Detection" indicates that the defect or the fault exists.

Again, if we intend to combine several antecedents using the traditional operators that used to be in traditional or in fuzzy inference systems which are (AND, OR, NOT), but in neutrosophic theory, we need to establish new operators called (ANOR, NOT ANOR), the operator (ANOR) is neither "AND" nor "OR", but it is the value between them, the following neutrosophic operators are considered in banding the neutrosophic statements:

- AND operator: it means to select the minimum weight of all combined antecedents.
- OR operator: it means to select the maximum weight of all combined antecedents.
- Not operator: it is the resulting value of subtracting 2 minus the (truth membership function plus indeterminacy membership function) to give the complementary function.
- ANOR operator: it is resulting from the equation $\frac{AND\ operator\ result+OR\ operator\ result}{2}$ that is mean (the minimum weight of all combined antecedents plus the maximum weight of all combined antecedents divided by two).
- Not ANOR: it is the value resulting from the formula $1-\frac{AND\ operator\ result+OR\ operator\ result}{2}$, which is exactly the complement of the operator ANOR.

The above neutrosophic operators have been created by the Ph.D. student (Ahemd K. Essa) and first appeared in this dissertation similar to the proposed neutrosophic inference system that was presented newly in this work (i.e. field of research that did not fathomless yet).

In the fuzzy inference systems, the most popular shapes of membership functions are the triangular, trapezoidal, and bell curves, but the shape is generally less important than the number of curves and their placement, from three to seven curves are generally appropriate to cover the required range of an input value in fuzzy inference system. The neutrosophic inference system will differ in taking the curves, we will depend on the truth membership function for those antecedents (i.e. inputs) and consequents (i.e. outputs) that belong to the truth spectrum, indeterminate membership functions are dedicated to those antecedents and consequents that represent the spectrum of indeterminacy, similarly, the falsity membership functions have been specified for those antecedents and consequences that represent the spectrum of falsity. So, the shape of the membership functions in the neutrosophic inference systems are as important as number of curves and their placements.

4. Suggestions to Modify MIL-STD-1629A

The generality and speedily used standard is MIL-STD-1629A. with more than four decades of years' usage and improvements, it has been utilized in various industries for failure mode, effects, and criticality analysis (FMECA). The objective of a FMCA is to identify all modes of failure within a system design, its first purpose is the early identification of all catastrophic and critical failure possibilities so they can be eliminated or minimized through design correction at the earliest possible time [16].

4.1 Pioneering Neutrosophic Thoughts in Modifying MIL-STD-1629A

To replace the severity classification categories that were stated in section 4.4.3, page 9 of MIL-STD-1629A, issued on 24 NOVEMBER 1980 into new categories in the perspective of neutrosophic theory, we can customize the following components with their appropriate membership function:

Neutrosophic Bias	IF + Antecedent Statement	AND + Antecedent Statement	THEN + Consequence Statement	The membership function concerning to the neutrosophic bias
Truth	IF the primary function can be done	And un-urgent repair is required	Then the risk severity on the power transformer is minor-minor	All statements in this row are adhering to the truth membership function represented by (6)
indeterminacy	IF the primary function can be done	And urgent repair is required	Then the risk severity on the power transformer is rather-minor	The last two statements in this row are adhering to the Indeterminacy membership function represented by (7)
falsity	IF the primary function can be done	And very-urgent repair is required	Then the risk severity on the power transformer is minor	The last two statements in this row are adhering to the falsity membership function represented by (8)
Truth	IF there is a few reduction in the ability to implement the primary function	…………………….	Then the risk severity on the power transformer is mini-marginal	All statements in this row are adhering to the truth membership function represented by (6)
Indeterminacy	IF there is a normal reduction in the ability to implement the primary function	…………………	Then the risk severity on the power transformer is a rather-marginal	All statements in this row are adhering to the Indeterminacy membership function represented by (7)

Falsity	IF there is an extremely reduction in the ability to implement the primary function	…………………	Then the risk severity on the power transformer is a marginal	All statements in this row are adhering to the falsity membership function represented by (8)

Table (4): Severity Rules distributed to its neutrosophic bias

Suppose the following variables represent the corresponding statements:

Table 5: Encoding the truth, indeterminacy, and falsity statements to its corresponding variable $\#_i$.

Neutrosophic Variables $\#_i$	**Corresponding Statements**	**Neutrosophic bias**
$\#_1$	the primary function can be done	Truth bias
$\#_2$	un-urgent repair is required	Truth bias
$\#_3$	the risk severity on the power transformer is minor-minor	Truth bias
$\#_4$	urgent repair is required	Indet. bias
$\#_5$	the risk severity on the power transformer is rather-minor	Indet. bias
$\#_6$	very-urgent repair is required	Falsity bias
$\#_7$	The risk severity on the power transformer is minor	Falsity bias
$\#_8$	There is a few reduction in the ability to implement the primary function	Truth bias
$\#_9$	The risk severity on the power transformer is a mini-marginal	Truth bias
$\#_{10}$	There is a normal reduction in the ability to implement the primary function	Indet. bias
$\#_{11}$	The risk severity on the power transformer is a rather-marginal	Indet. bias
$\#_{12}$	There is an extremely reduction in the ability to implement the primary function	Falsity bias
$\#_{13}$	The risk severity on the power transformer is a marginal	Falsity bias

For all $\#_i$, $i = 1,2,3,8,9$ the following truth membership function is recommended

$$\xi_A(\#_i) = \begin{cases} 0 & \#_i \leq 0.4 \\ (\frac{\#_i - 0.4}{2})^2 & 0.4 < \#_i \leq 2 \\ 1 & \#_i > 2 \end{cases} \quad (6)$$

For all $\#_i$, $i = 4,5,10,11$ the following indeterminacy membership function should be taken

$$\varpi_A(\#_i, 0.4, 2) = \begin{cases} (\frac{\#_i - 0.4}{1.6})^2 & 0.4 \leq \#_i < 1.6 \\ \frac{1}{2} - \left(\frac{\#_i - 1.6}{2}\right)^2 & 1.6 \leq \#_i < 2 \\ 0 & 2 \leq \#_i < 0.4 \end{cases} \quad (7)$$

Finally, those $\#_i$, $i = 6,7,12,13$ have to be shapes according to the following falsity membership function:

$$\Upsilon_A(\#_i) = \begin{cases} 1 & \#_i \leq 0.4 \\ 1 - (\frac{\#_i - 0.4}{2})^2 & 0.4 < \#_i \leq 2 \\ 0 & \#_i > 2 \end{cases} \quad (8)$$

It should be noticed that the expert has free choice in adopting the truth membership function, but, once he/ she decides to adopt a specific one, the remaining indeterminacy and falsity functions must follow the behaviour of his choice as it refers to in the equation (2).

5. Build Neutrosophic Inference System Using Custom Functions

Due to the fuzzyLogicDesigner app and the MATLAB® command lines are not supplied with the ability to specify the neutrosophic statements to their appropriate truth, indeterminacy, and falsity membership functions, as well as, fuzzyLogicDesigner lacks to contain other operators except the traditional inference functions (AND, OR), which are inadequate for the representation of neutrosophic argues, therefore, this section has been dedicated to program new operators (i.e. custom functions) ANOR, NOT ANOR, in addition to program all neutrosophic inference system requirements.

5.1 Programming the Truth Membership Function

Now, the creation custom truth membership function is the aiming step, regarded as the preparation step to use it in the neutrosophic inference system. It is clear that the following MATLAB commands are plotting the truth membership function that mathematically represents the equation (6), and it lies between 0 and 1.

```
% plot the diagram of truth membership function
clc;
clear;
close;
syms x
f1=((x-0.4)/2)^2;
figure
obj=fplot(f1,[0.4 2.4])
hold on
fplot(0,[0 0.4])
fplot(1,[2.4 3.0])
hold off
title('figure1:truthmf')
xlabel('input values')
ylabel('truth membership function')
ylim([-0.06 1.06])
```

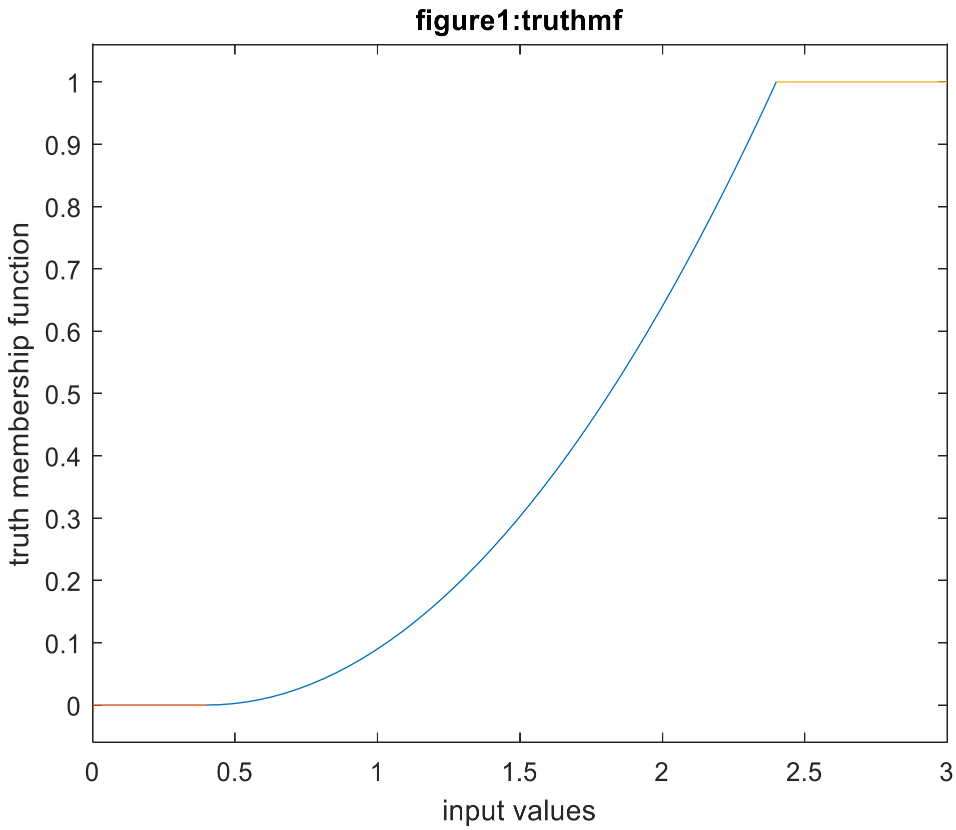


Figure 5.1: the graph of truth membership function $\xi_A(\#_i), i = 1,2,3,8,9$

5.2 Programming the Falsity Membership Function

Again using the similarly commands goes to plot the mathematical representation of falsity membership function that was presented in equation (8),

```
% plot the diagram of falsity membership function
clc;
clear;
close; syms x
f2=1-(((x-0.4)/2)^2);
figure
obj=fplot(f2,[0.4 2.4])
hold on
fplot(1,[0 0.4])
```

```
fplot(0,[2.4 3.0])
hold off
title('figure2:falsitymf')
xlabel('input values')
ylabel('falsity membership function')
ylim([-0.06 1.06])
```

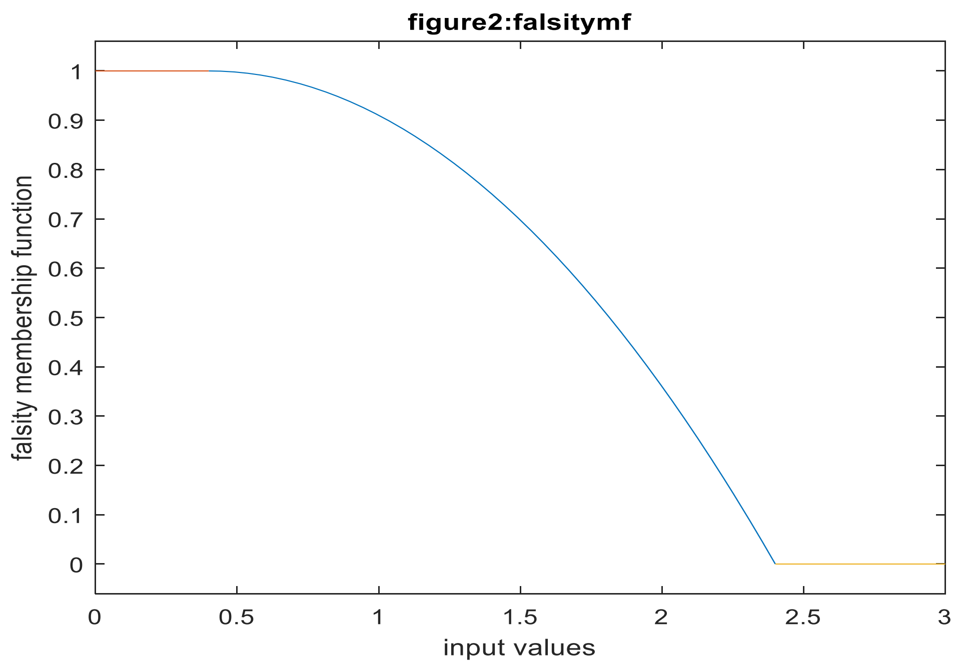


Figure 5.2: the graph of falsity membership function $\Upsilon_A(\#_i), i = 6,7,12,13$

5.3 Programming the Indeterminacy Membership Function

Again, the concept of the indeterminacy function is that function which swings between the truth and the falsity membership functions for the same neutrosophic object (variable, element, number… etc.), that is, the intersection of them represents the indeterminacy function. The following MATLAB syntax demonstrates the region

```
% plot the curve of the indeterminacy memebership function which is the
% intersection of both truth membership function and falsity membership % function
```

```
clc;
clear;
close;
syms x
f1=((x-0.4)/2)^2;
f2=0.5-(((x-0.4)/2)^2);
figure
obj=fplot(f2,[1.4 1.82])
hold on
obj=fplot(f1,[0.4 1.4])
fplot(0,[0 0.4])
fplot(0,[1.80091 3])
hold off
title('figure3:indeterminacymf')
xlabel('input values')
ylabel('indeterminacy membership function')
ylim([-0.06 1.06])
```

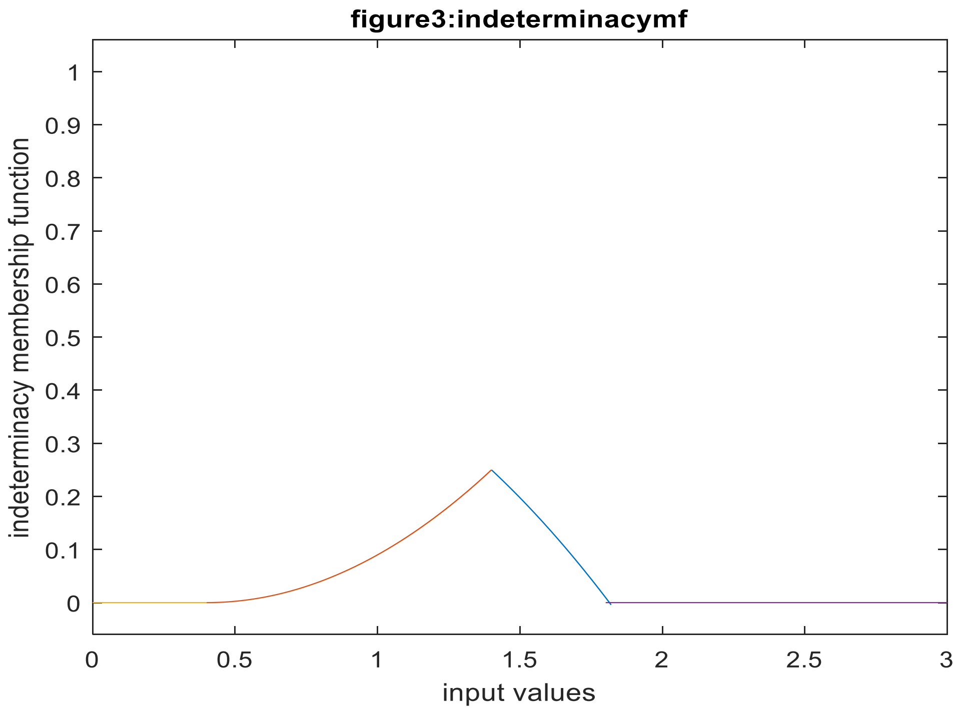


Figure 5.3: the graph of indeterminacy membership function $\varpi_A(\#_i, 0.4, 2), i = 4,5,10,11$

5.4 Create Custom Inference Functions

Since the MATLAB Toolbox of fuzzy inference systems (FIS) is void of features that support the operators ANOR, and NOT ANOR. Furthermore, the MATLAB Toolbox completely unsupported with Neutrosophic Inference System (NIS) which built-in AND, OR, implication, aggregation, and deneutrosophication, this forced us to the strategy of partial use of a FIS with some modification through custom-specific operators and adapted functions of (FIS) to be appropriate for neutrosophic Inference System (NIS), this will be done by the following clauses:

Note that: when the custom inference system has been created, we should save it in our current working folder or on the MATLAB path, this will enable us to design a NIS that uses the custom inference function at the command line or in *AddaptedFuzzyLogicDesigner* app.

In Neutrosophic Logic Toolbox™ software that should be built in Matlab we have:

- AND inference function performs an element by element matrix operation, similar to the command min, see the following example:

```
clc;
clear;
close;
x=[0.5 1;3 0.7];
y=[0.32 5;0.79 2];
ANDOperator=min(x,y)
```

```
ANDOperator =
  0.3200    1.0000
  0.7900    0.7000
```

- OR inference function performs an element by element matrix operator, similar to the command max, the following example illustrates the operator:

```
clc;
clear;
close;
x=[0.5 1;3 0.7];
y=[0.32 5;0.79 2];
OROperator=max(x,y)
```

```
OROperator =
  0.5000    5.0000
  3.0000    2.0000
```

- ANOR inference function performs an element by element matrix operator, similar to the command (max+min)/2, the following example illustrates the operator:

```
clc;
```

```
clear;
close;
x=[0.5 1;3 0.7;2.1 0.56];
y=[0.32 5;0.79 2;8.1 1.03];
ANOROperator=(max(x,y)+min(x,y))/2
```

```
ANOROperator =
 0.4100    3.0000
 1.8950    1.3500
 5.1000    0.7950
```

- NOT ANOR inference function performs an element by element matrix operator, similar to the command 1-(max+min)/2, the upcoming example is demonstrating the requirement:

```
x=[0.5 1;3 0.7;2.1 0.56];
y=[0.32 5;0.79 2;8.1 1.03];
ANOROperator=1-((max(x,y)+min(x,y))/2)
```

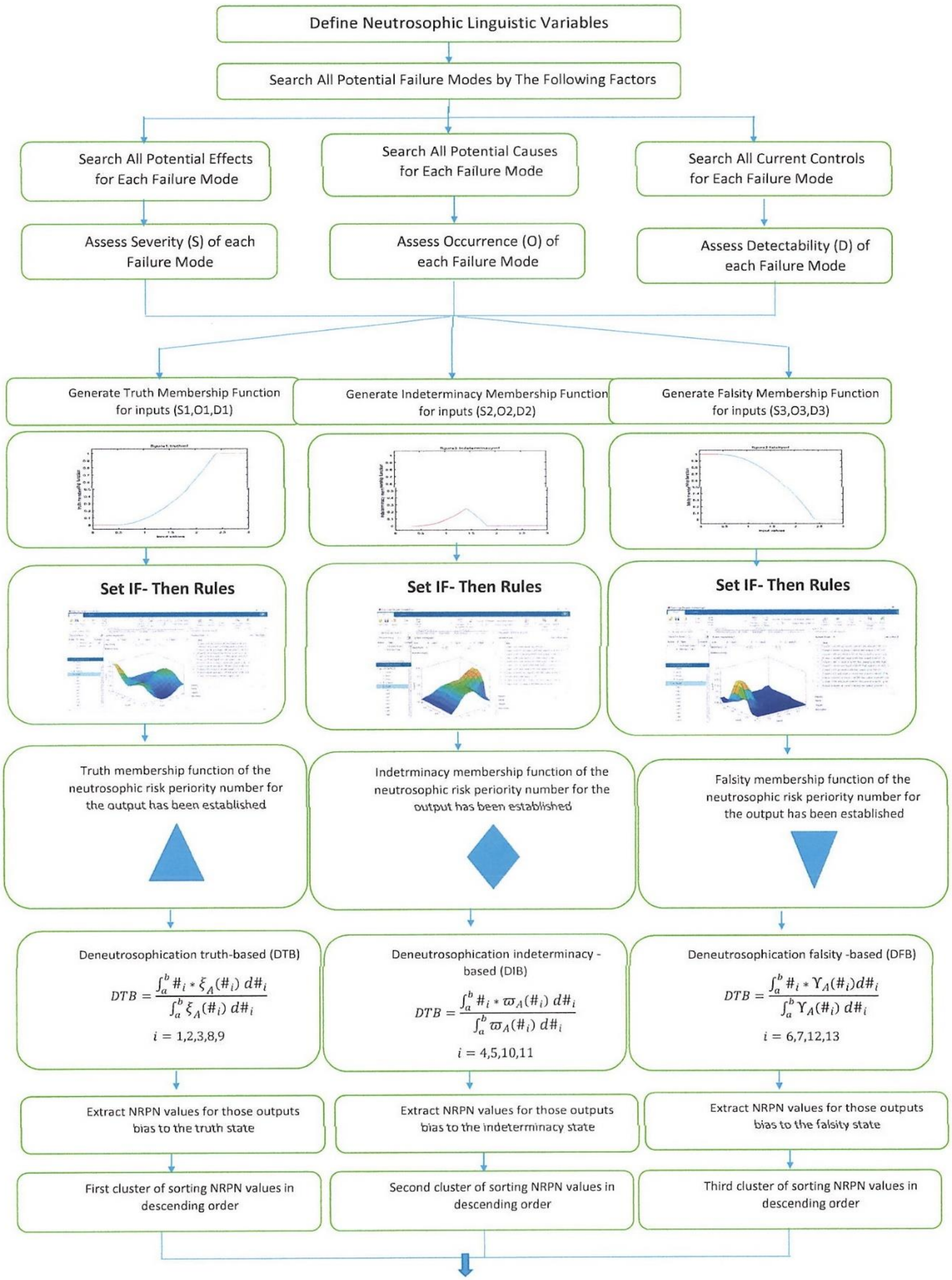
```
ANOROperator =
  0.5900   -2.0000
 -0.8950   -0.3500
 -4.1000    0.2050
```

6. Neutrosophic FMEA Flow Chart

The scaling of the three factors (i.e. Severity, Detection, and Occurrence) which were manifested in Tables (1,2 & 3), leads us to produce the flowchart of NFMEA which is presented in Figure 2 containing the algorithm of neutrosophic failure mode effect analysis to conduct the neutrosophic risk priority ranking.

We should state that the general defect analysis of the power transformers in this manuscript concerning its severity classification and its occurrence classification are scaling by using adapted MIL-STD-1629 standard, this adaptation is to meet our requirements that came from the neutrosophic theory were tabulated in tables (1&2). furthermore, our adaptation technique of the CIGRE working group on power transformer [11] is used to scale the detection factor for diagnostic tests tabulated in Table (3).

Without loss of generality, our algorithm for the neutrosophic inference system dependent on Mamdani type-1- method with customizing (truth, indeterminacy, and falsity) membership functions for inputs and outputs, and the neutrosophic risk priority number NRPN will be partitioned into three categories, NRPN truth-biased, NRPN indeterminacy-biased, finally NRPN falsity-biased. For each faulty cause, the controls that are currently in place in order to reduce or eliminate the risk linked with potential defective reason should be noted.


Define Neutrosophic Linguistic Variables
Search All Potential Failure Modes by The Following Factors
Search All Potential Effects for Each Failure Mode
Search All Potential Causes for Each Failure Mode
Search All Current Controls for Each Failure Mode
Assess Severity (S) of each Failure Mode
Assess Occurrence (O) of each Failure Mode
Assess Detectability (D) of each Failure Mode
Generate Truth Membership Function for inputs (S1,O1,D1)
Generate Indeterminacy Membership Function for inputs (S2,O2,D2)
Generate Falsity Membership Function for inputs (S3,O3,D3)
Set IF- Then Rules
Set IF- Then Rules
Set IF- Then Rules
Truth membership function of the neutrosophic risk periority number for the output has been established
Indetrminacy membership function of the neutrosophic risk periority number for the output has been established
Falsity membership function of the neutrosophic risk periority number for the output has been established
Deneutrosophication truth-based (DTB)
$DTB = \frac{\int_a^b \#_i * \xi_A(\#_i)\, d\#_i}{\int_a^b \xi_A(\#_i)\, d\#_i}$
$i = 1,2,3,8,9$
Deneutrosophication indeterminacy - based (DIB)
$DTB = \frac{\int_a^b \#_i * \varpi_A(\#_i)\, d\#_i}{\int_a^b \varpi_A(\#_i)\, d\#_i}$
$i = 4,5,10,11$
Deneutrosophication falsity -based (DFB)
$DTB = \frac{\int_a^b \#_i * \Upsilon_A(\#_i) d\#_i}{\int_a^b \Upsilon_A(\#_i)\, d\#_i}$
$i = 6,7,12,13$
Extract NRPN values for those outputs bias to the truth state
Extract NRPN values for those outputs bias to the indeterminacy state
Extract NRPN values for those outputs bias to the falsity state
First cluster of sorting NRPN values in descending order
Second cluster of sorting NRPN values in descending order
Third cluster of sorting NRPN values in descending order

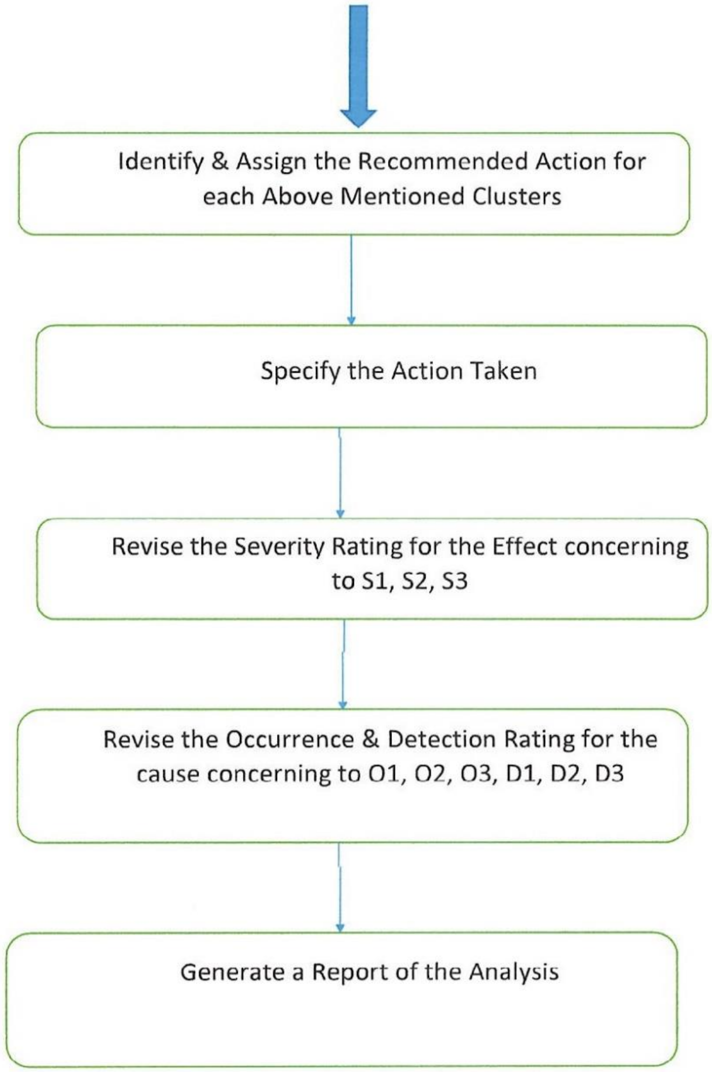


Figure 2: Algorithm of NFMEA creation

7. Components of the Power Transformer Dependent in this Work

In this work, we will depend on the same components of the oil-immersed power transformers that have been adopted by [2], which are:

1- The active part is composed of the Core and its function is to concentrate the magnetic flux. Windings have the function of carrying current.

2- The insulation system consists of two parts, a liquid part called transformer oil, and a solid part which is cellulose.

3- Accessories are firstly composed of bushings that insulate a high-voltage conductor passing through a metal enclosure. The second component is the tap changer which is the most complex component of the transformer and its function is to regular the voltage level by adding or subtracting turns from the transformer windings. The third component is the cooling System consists of cooling fans which is designed to remove the heat caused by copper and iron losses. The fourth component is the tank is primarily the container for the oil and physical protection for the active part. The fifth component is the mechanical structure which includes clamping, coil blocking, and lead support, their function is to support the active part of the transformer firmly in its place and withstand against mechanical stresses. The sixth and final part is winding connections which are between windings, tap leads, and bushings, their function is to provide the required electrical connection between these elements.

4- Protection is the primary objective of transformer protection which is used to detect internal faults in the transformer with a high degree of sensitivity and cause subsequent de-energization and, at the same time be immune to faults external to the transformer.

8. Power Transformer Neutrosophic Failure Mode Effect Analysis (NFMEA)

Similar to the severity rules distributed to the neutrosophic bias that has been done in table (4), we will create the same distributed rules for the occurrence and the severity of failure modes:

Neutrosophic Bias	IF + Antecedent Statement	THEN + Consequence Statement	The membership function concerning to the neutrosophic bias
Truth	IF a single failure mode probability of occurrence is less than 0.001	THEN the probability of the risk occurrence on the power transformer is extremely unlikely.	All statements in this row are adhering to the truth membership function represented by (6)

Truth	IF a single failure mode probability of occurrence is less than 0.01	THEN the probability of the risk occurrence on the power transformer is unlikely.	All statements in this row are adhering to the truth membership function represented by (6)
Indeterminacy	IF a single failure mode probability of occurrence is less than 0.1	THEN the probability of the risk occurrence on the power transformer is occasional.	All statements in this row are adhering to the Indeterminacy membership function represented by (7)
Indeterminacy	IF a single failure mode probability of occurrence is less than 0.	THEN the probability of the risk occurrence on the power transformer is reasonably probable.	All statements in this row are adhering to the Indeterminacy membership function represented by (7)
Falsity	IF a single failure mode probability of occurrence is greater than 0.2	THEN the probability of the risk occurrence on the power transformer is sometimes frequent.	All statements in this row are adhering to the falsity membership function represented by (8)
Falsity	IF a single failure mode probability of occurrence is greater than 0.3	THEN the probability of the risk occurrence on the power transformer is permanently frequent.	The last two statements in this row are adhering to the falsity membership function represented by (8)

Table (6): Occurrence Rules Distributed to its Neutrosophic Bias

Neutrosophic Bias	IF + Antecedent Statement	THEN + Consequence Statement	The membership function concerning to the neutrosophic bias
Truth	IF the problem has been well identified	THEN the problem will be completely fixed before the electricity services reach to the customer.	All statements in this row are adhering to the truth membership function represented by (6)

Truth	IF the problem has been fairly identified	THEN the problem will be fixed before the electricity services reach to the customer.	All statements in this row are adhering to the truth membership function represented by (6)
Indeterminacy	IF the problem has been well detected AND rough identification	THEN the problem will be nearly fixed before the electricity services reach to the customer.	All statements in this row are adhering to the Indeterminacy membership function represented by (7)
Indeterminacy	IF the problem has been fairly detected	THEN the problem will cause a delay in reaching the electricity services to the customer.	All statements in this row are adhering to the Indeterminacy membership function represented by (7)
Falsity	IF the problem has been roughly detected	THEN the problem will cause a temporary pause in the system.	All statements in this row are adhering to the falsity membership function represented by (8)
Falsity	IF the system needs to complementary test	THEN the problem will cause a pause in the system.	All statements in this row are adhering to the falsity membership function represented by (8)

Table (7): Detection Rules Distributed to its Neutrosophic Bias

The following table (8) illustrates sixty-three of (IF-AND-THEN-ANOR) rules for seven components of the power transformer:

1- Solid Insulation: which has the function of insulation of windings, where its failure mode is physical and chemistry.
2- Oil Insulation: which has the function of isolating and cooling the active part of the transformer, where its failure mode is physical and chemistry.
3- Windings: which has the function of conducting current, where its failure mode is mechanical.

4- Tank: This has the function of enclosing oil and protecting the active part of the transformer, where its failure mode is chemical and physical.

5- Bushings: has the function of connecting windings with the net, and isolating between tank and windings. Also, its failure mode is physical and chemical.

6- Core: has the function of containing the magnetic field, and its failure mode is thermal.

7- Diverter switch: has the function of maintaining a coherent current, and its failure mode is electrical.

able (8): IF-THEN Rules for Some Power Transformer Components

Components	Number of rules and Neutrosophic Bias	IF (Antecedent) or/and/anor (Antecedent) THEN (Consequence) or/and/anor (Consequence)
Oil Insulation	R1 Truth	IF the probability of particle contamination occurrence is less than 0.001 OR less than 0.01 THEN the reduction of the electrical strength AND the reduction of the breakdown voltage AND the increase in dielectric loss of oil is extremely unlikely OR unlikely. **ANOR** IF the probability of particle contamination occurrence is less than 0.001 or less than 0.01 THEN the overheating AND short circuit in the transformer is extremely unlikely OR unlikely. **ANOR** IF there is a pump bearing monitor AND there is a correct oil sampling procedure THEN the breakdown voltage will be completely fixed before the electricity services reach the customer.
	R2 Indeterminacy	IF the probability of particle contamination occurrence is less than 0.1 OR less than 0.2 THEN the reduction of the electrical strength AND the reduction of the

		breakdown voltage AND the increase in dielectric loss of oil is occasional OR reasonably probable **ANOR** IF the probability of particle contamination occurrence is less than 0.1 or less than 0.2 THEN the overheating AND short circuit in the transformer is occasional OR reasonably probable **ANOR** IF there is well detection for the pump bearing monitor AND there is rough identification for the correct oil sampling THEN there will be nearly correction of the breakdown voltage before the electricity services reach the customer
	R3 Falsity	IF the probability of particle contamination occurrence is greater than 0.2 OR greater than 0.3 THEN the reduction of the electrical strength AND the reduction of the breakdown voltage AND the increase in dielectric loss of oil is sometimes frequent OR permanently frequent. **ANOR** IF the probability of particle contamination occurrence is greater than 0.2 or greater than 0.3 THEN the overheating AND short circuit in the transformer is sometimes frequent OR permanently frequent. **ANOR** IF there is not a pump bearing monitor AND there is not a correct oil sampling procedure THEN the breakdown voltage will never fixed before the electricity services reach the customer.

Solid Insulation	R4 Truth	IF the probability of the excessive moisture occurrence is less than 0.001 OR less than 0.01 THEN the reduction of the dielectric AND the reduction of the mechanical strength of paper is extremely unlikely OR unlikely **ANOR** IF the probability of the excessive moisture occurrence is less than 0.001 OR less than 0.01 THEN the Mechanical damage AND fault in insulation is extremely unlikely OR unlikely **ANOR** IF we prevent free transportation of the oil AND there is the prevention of direct entry of moisture from the air by the proper sealing THEN the oil moisture will be completely avoidable
	R5 Indeterminacy	IF the probability of the excessive moisture occurrence is less than 0.1 OR less than 0.2 THEN the reduction of the dielectric AND the reduction of the mechanical strength of paper is occasional OR reasonable probable. **ANOR** IF the probability of the excessive moisture occurrence is less than 0.1 OR less than 0.2 THEN the Mechanical damage AND fault in insulation is occasional OR reasonable probable. **ANOR** IF we often prevent the free transportation of the oil AND there is often prevention of direct entry of moisture from the air by the proper sealing THEN the oil moisture will be nearly avoidable.

	R6 Falsity	IF the probability of the excessive moisture occurrence is greater than 0.2 OR greater than 0.3 THEN the reduction of the dielectric AND the reduction of the mechanical strength of paper is sometimes frequent OR permanently frequent. **ANOR** IF the probability of the excessive moisture occurrence is greater than 0.2 OR greater than 0.3 THEN the Mechanical damage AND fault in insulation is sometimes frequent OR permanently frequent. **ANOR** IF we do not prevent free transportation of the oil AND there is not prevention of direct entry of moisture from the air by the proper sealing THEN the oil moisture will not be avoidable
Windings	R7 Truth	IF the probability of the loose clamping occurrence is less than 0.001 OR less than 0.01 THEN the winding deformation is extremely unlikely OR unlikely. **ANOR** IF the probability of the loose clamping occurrence is less than 0.001 OR less than 0.01 THEN the high through current faults AND high inrush current AND protective relay tripping are extremely unlikely OR unlikely **ANOR** IF we use higher density insulation AND use of higher clamping pressures during manufacturing AND we use spring dashpot assemblies on the coil clamping structure THEN the loose clamping will be completely avoidable

	R8 Indeterminacy	IF the probability of the loose clamping occurrence is less than 0.1 OR less than 0.2 THEN the winding deformation is occasional OR reasonable probable. **ANOR** IF the probability of the loose clamping occurrence is less than 0.1 OR less than 0.2 THEN the high through current faults AND high inrush current AND protective relay tripping are occasional OR reasonable probable. **ANOR** IF we often use higher density insulation AND often use of higher clamping pressures during manufacturing AND we often use spring dashpot assemblies on the coil clamping structure THEN the loose clamping will be nearly avoidable
	R9 Falsity	IF the probability of the loose clamping occurrence is greater than 0.2 OR greater than 0.3 THEN the winding deformation is sometimes frequent OR permanently frequent. **ANOR** IF the probability of the loose clamping occurrence is greater than 0.2 OR greater than 0.3 THEN the high through current faults AND high inrush currents AND protective relay tripping is sometimes frequent OR permanently frequent. **ANOR** IF we could not use higher density insulation AND could not use of higher clamping pressures during manufacturing AND we could not use spring dashpot

		assemblies on the coil clamping structure THEN the loose clamping will not be avoidable.
Tank	R10 Truth	IF the probability of the insufficient maintenance occurrence is less than 0.001 OR less than 0.01 THEN the corrosion is extremely unlikely OR unlikely. **ANOR** IF the probability of the insufficient maintenance occurrence is less than 0.001 OR less than 0.01 THEN the leakage is extremely unlikely OR unlikely. **ANOR** IF we use monitoring of the inhibitor content according to IEC 60666 AND there is external examination for oil leaks THEN any corrosion will be completely avoidable.
	R11 Indeterminacy	IF the probability of the insufficient maintenance occurrence is less than 0.1 OR less than 0.2 THEN the corrosion is occasional OR reasonably probable. **ANOR** IF the probability of the insufficient maintenance occurrence is less than 0.1 OR less than 0.2 THEN the leakage is occasional OR reasonably probable. **ANOR** IF we often use the monitoring of the inhibitor content according to IEC 60666 AND often there is an external examination for oil leaks THEN any corrosion will be nearly avoidable.
	R12 Falsity	IF the probability of the insufficient maintenance occurrence is greater than 0.2 OR greater than 0.3 THEN the corrosion is sometimes frequent OR permanently frequent.

		ANOR IF the probability of the insufficient maintenance occurrence is greater than 0.2 OR greater than 0.3 THEN the leakage is sometimes frequent OR permanently frequent. **ANOR** IF we do not use monitoring of the inhibitor content according to IEC 60666 AND there is not external examination for oil leaks THEN any corrosion will not be avoidable.
Bushings	R13 Truth	IF the lack of maintenance is less than 0.001 OR less than 0.01 THEN the external contamination corrosion AND the discharge current on the external surface of the insulation is extremely unlikely OR unlikely. **ANOR** IF the lack of maintenance is less than 0.001 OR less than 0.01 THEN the short circuit AND the personal danger is extremely unlikely OR unlikely. **ANOR** IF there is periodic maintenance THEN the power factor will adhere the standard (IEC 137)/ tan delta.
	R14 Indeterminacy	IF the lack of maintenance is less than 0.1 OR less than 0.2 THEN the external contamination corrosion AND the discharge current on the external surface of the insulation is occasional OR reasonable probable. **ANOR** IF the probability of the lack of maintenance is less than 0.1 OR less than 0.2 THEN the short circuit AND the personal danger is occasional OR reasonable probable.

		ANOR IF there is often periodic maintenance THEN the power factor will often adhere the standard (IEC 137)/ tan delta.
	R15 Falsity	IF the lack of maintenance is greater than 0.2 OR greater than 0.3 THEN the external contamination corrosion AND the discharge current on the external surface of the insulation is sometimes frequent OR permanently frequent. **ANOR** IF the lack of maintenance is greater than 0.2 OR greater than 0.3 THEN the short circuit AND the personal danger is sometimes frequent OR permanently frequent. **ANOR** IF there is not periodic maintenance THEN the power factor will not adhere the standard (IEC 137)/ tan delta.
Core	R16 Truth	IF the probability of the inexistence of the frame to earth circulating currents is less than 0.001 OR less than 0.01 THEN the increased core temperature is extremely unlikely OR unlikely. **ANOR** IF the probability of the inexistence of the frame to earth circulating currents is less than 0.001 OR less than 0.01 THEN the loss of efficiency is extremely unlikely OR unlikely. **ANOR** IF there exist the frame to earth circulating currents THEN there is not increased core temperature.

	R17 Indeterminacy	IF the probability of the inexistence of the frame to earth circulating currents is less than 0.1 OR less than 0.2 THEN the increased core temperature is occasional OR reasonably probable. **ANOR** IF the probability of the inexistence of the frame to earth circulating currents is less than 0.1 OR less than 0.2 THEN the loss of efficiency is occasional OR reasonably probable. **ANOR** IF the often inexistence of the frame to earth circulating currents THEN the increased core temperature is often detected and often identification by Furfuraldehyde Analysis (FFA).
	R18 Falsity	IF the probability of the inexistence of the frame to earth circulating currents is greater than 0.2 OR greater than 0.3 THEN the increased core temperature is sometimes frequent OR permanently frequent. **ANOR** IF the probability of the inexistence of the frame to earth circulating currents is greater than 0.2 OR greater than 0.3 THEN the loss of efficiency is sometimes frequent OR permanently frequent. **ANOR** IF the inexistence of the frame to earth circulating currents THEN the increased core temperature is detected and identification by Furfuraldehyde Analysis (FFA).
	R19 Truth	IF the probability of the worry contact occurrence is less than 0.001 OR less than 0.01 THEN the existence of

Diverter Switch		a high carbon build-up is extremely unlikely OR unlikely. **ANOR** IF the probability of the worry contact occurrence is less than 0.001 OR less than 0.01 THEN the existence of possible flash over is extremely unlikely OR unlikely. **ANOR** IF there is not worry contact THEN we do not need to the contact replacement after the specified performance number according to the manufacturer suggestions.
	R20 Indeterminacy	IF the probability of the worry contact occurrence is less than 0.1 OR less than 0.2 THEN the existence of a high carbon build-up is occasional OR reasonable probable. **ANOR** IF the probability of the worry contact occurrence is less than 0.1 OR less than 0.2 THEN the existence of possible flash over is occasional OR reasonable probable. **ANOR** IF there is often a worry contact THEN we will often contact replacement after the specified performance number according to the manufacturer's suggestions.
	R21 Falsity	IF the probability of the worry contact occurrence is greater than 0.2 OR greater than 0.3 THEN the existence of a high carbon build-up is sometimes frequent OR permanently frequent. **ANOR** IF the probability of the worry contact occurrence is greater than 0.2 OR less than 0.3 THEN the existence of

		possible flash over is sometimes frequent OR permanently frequent. **ANOR** IF there is worry contact THEN the contact replacement after the specified performance number according to the manufacturer suggestions.

9. Implement NFMEA using NeutrosophicLogicDesigner

As previously discussed, the MATLAB Toolbox suffers from uncontained for a neutrosophic logic based-inference system, therefore, the researcher was forced to use the fuzzyLogicDesigner after adapting it by using specific membership functions, specific operators...etc. However, the implementation will be on the type-1 Mamdani inference system.

To abbreviate the simulation, we tried to apply the Type-1 Mamdani inference method on just three rules of the above table (8), especially the following rules

1- IF there is a pump bearing monitor AND there is a correct oil sampling procedure THEN the breakdown voltage will be completely fixed before the electricity services reach the customer.

2- IF there is well detection for the pump bearing monitor AND there is rough identification for the correct oil sampling THEN there will be nearly correction of the breakdown voltage before the electricity services reach the customer.

3- IF there is not a pump bearing monitor AND there is not a correct oil sampling procedure THEN the breakdown voltage will never fixed before the electricity services reach the customer.

In the neutrosophic inference rules, we noticed that there are different composites from the traditional patterns, where we linked every two opposite statements in one input by two opposite membership functions using the command (Evenly Distributed MFs), Also we gave opposite weights of opposite rules. As well as we also interpreted the statements of indeterminate bias by those membership functions that are embedded between two opposite membership functions (i.e. truth and false)

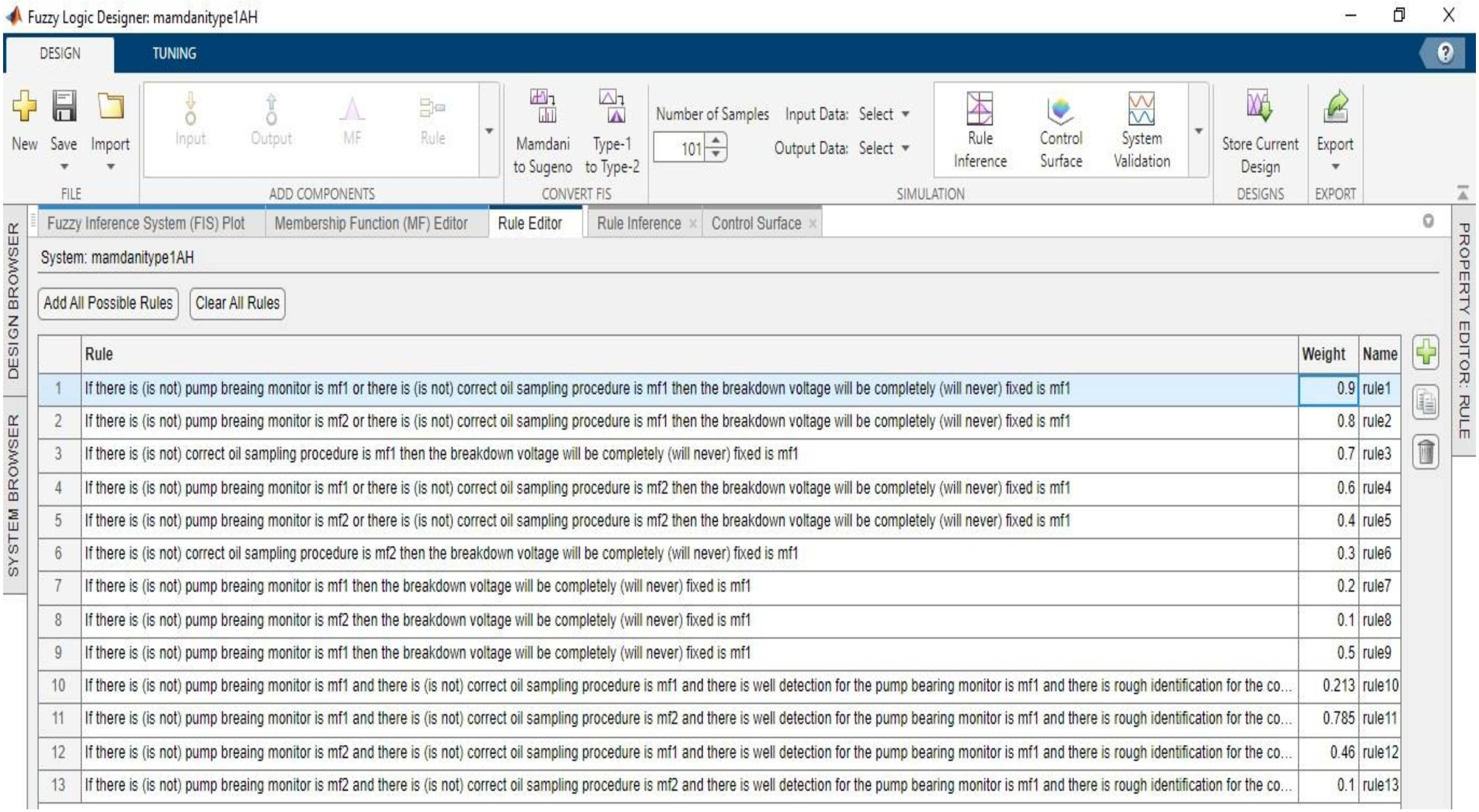


Figure 9.1: Some of the Defined Rules to Combine Neutrosophic (Severity, Occurrence and Detection) in MATLAB R2023a

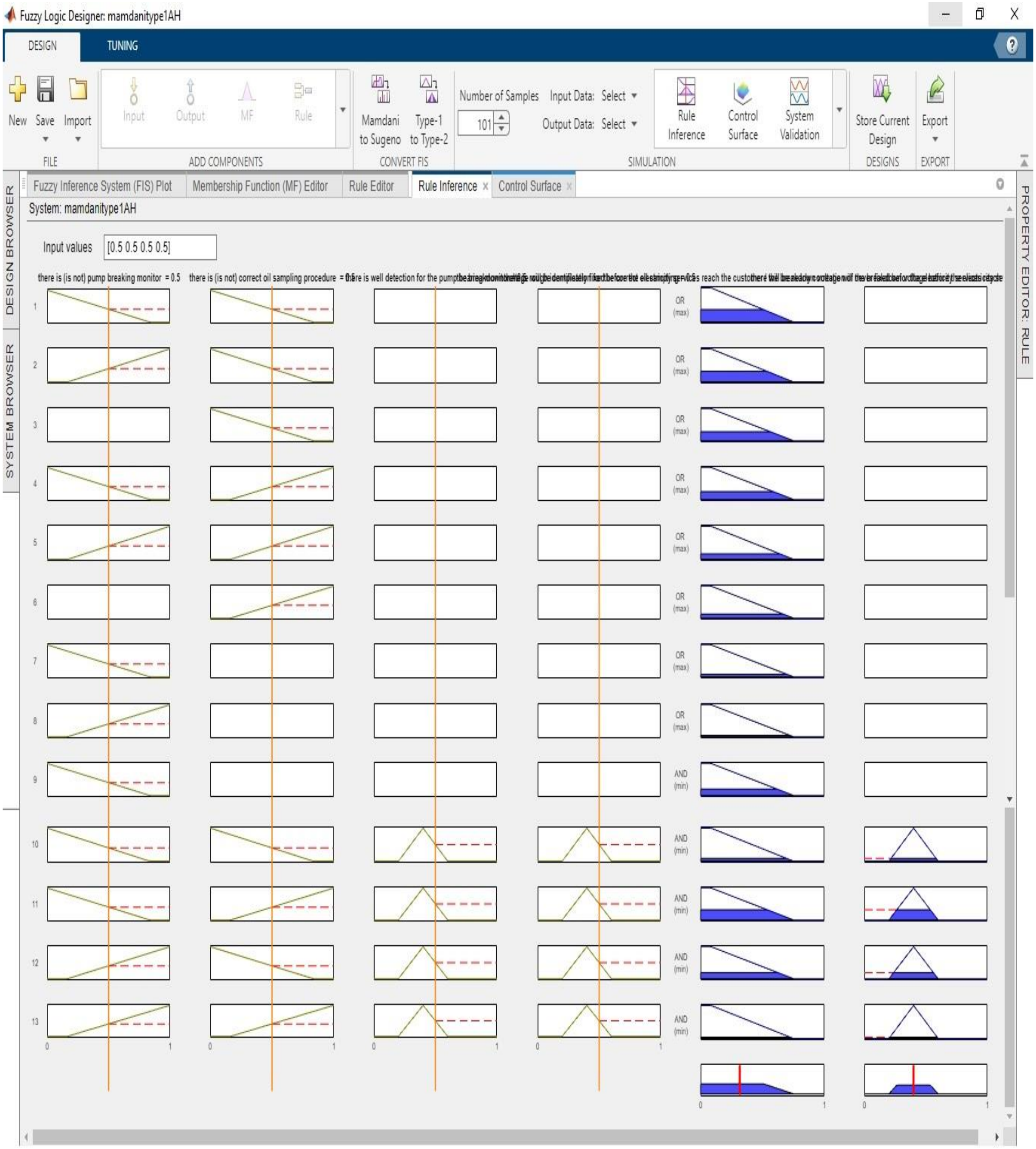


Figure 9.2: Implementation the Neutrosophic Inference Rules R1, R2, R3

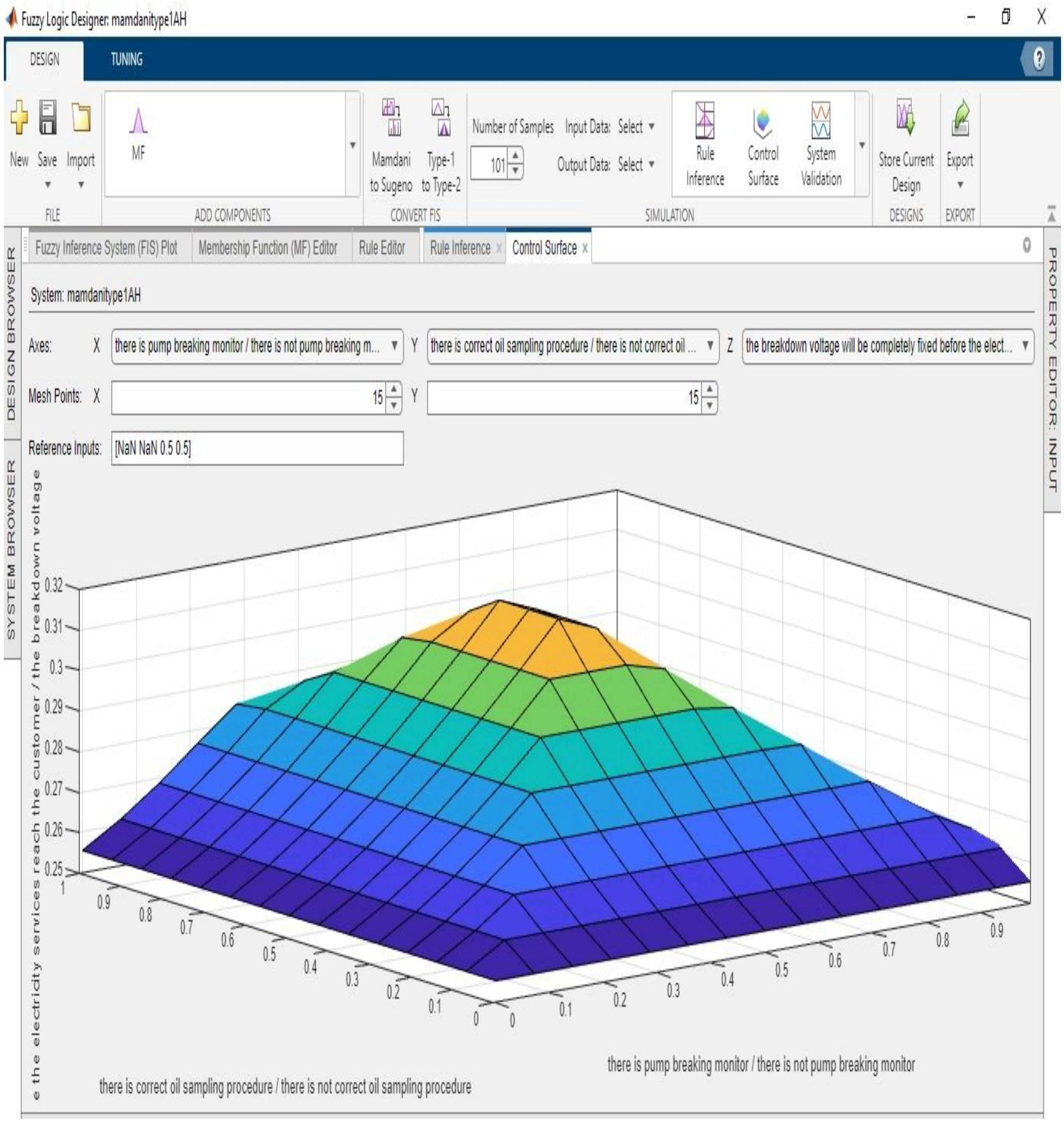


Figure 9.3: Surface of the Neutrosophic Inference System (NIS)

10. Neutrosophic Risk Priority Numbers

Analogs to the concept of the traditional FMEA, and fuzzy FMEA, the neutrosophic failure mode effect analysis assigns numerical values to every risk associated with causing failure, using severity, occurrence, and detection by calculating the neutrosophic risk priority number (NRPN) for each failure cause.

We should notice that, in the NFMEA, the definition of failure modes, failure causes and failure effects depend on the level of analysis and system failure criteria. As the analysis progress, the failure effects identified at the lower level may become failure modes at the higher level. The failure modes at the lower level may become the failure causes at the higher level, and so on [2].

10.1. Analysis results of the inferencing R1, R2, R3

The sake of this study is to put the principles of the neutrosophic inference system for the power transformers, and after putting all (IF-HEN) rules concerning the (severity, occurrence, not detection) of each failure mode belonging to seven components (Solid Insulation, Oil Insulation, Windings, Tank, Bushings, Core, and Diverter Switch), and since the MATLAB toolbox does not support the NIS which lead us to use the fuzzyLogicDesigner to build adaptive NeutrosophicLogicDesigner. Therefore, we tried to restrict the analysis to only three rules out of sixty-three rules stated in table (8). Also, the generalization concepts of the neutrosophic theory and its superiority to fuzzy logic, as well as, its superiority to classical logic, led to the creation of the operator (ANOR) which was never ever previously created neither in classical inference systems nor fuzzy inference systems. Again, the existence of the operator (ANOR) is regarded as a challenge preventing us from using all 63 rules stated in Table (8) for the same reason of unsupported fuzzyLogicDesigner to this kind of operator.

Now, if we track the trace of the thirteen rules resulting from R1, R2, and R3 (see figures 9.1 & 9.2) with different impacts in their weights for each rule depending upon the (severity, occurrence, not detection) if their bias to the truth state or to the indeterminate state or to the falsity state.

The ranking of each failure mode caused by its severity, occurrence, and not detection will be ranked in decreasingly order (the largest number of $NRPN = 6$ is the more truth situation having lowest risk impact that has lowest priority, while the smallest number of $NRPN = 1$ is the more falsity or more indeterminate situation having highest risk impact that has largest priority) of the neutrosophic risk priority number (NRPN) as demonstrated in the following table

Table (8): Neutrosophic Failure Mode Analysis in Power Transformers

No. of Rules	Control (s) Factor	Neutrosophic bias	Weight	Ranking of NRPN
1	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+Truth+Truth	0.9	6
2	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+ Falsity+Truth	0.8	5
3	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+Truth+Falsity	0.7	4
4	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+Indet.+Truth	0.6	4
5	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+Indet.+Falsity	0.4	3
6	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+Indet.+Indet.	0.3	3
7	Pump bearing factor+ breakdown voltage+ correct oil sampling	Truth+Truth+Indet	0.2	2
8	Pump bearing factor+ breakdown voltage+ correct oil sampling	Falsity+Falsity+Falsity	0.1	1
9	Pump bearing factor+ breakdown voltage+ correct oil sampling	Indet.+indet+indet	0.5	3
10	Pump bearing factor+ breakdown voltage+ correct oil sampling	Indet.+Indet.+Falsity	0.213	2
11	Pump bearing factor+ breakdown voltage+ correct oil sampling	Indet.+Indet.+Truth	0.785	4
12	Pump bearing factor+ breakdown voltage+ correct oil sampling	Indet.+falsity+Truth	0.46	3
13	Pump bearing factor+ breakdown voltage+ correct oil sampling	Falsity+Indet.+Falsity	0.1	1

11. Conclusion

In view of neutrosophic theory, many new concepts and procedures have been introduced in this manuscript, a modifying MIL-STD-1629A by re-presenting new categories of severity factors of failure mode that were stated and used since 1980. Also, the authors re-framed all failure modes (severity, occurrence, and not detection) of the electrical power transformer according to their neutrosophic bias. we create a mathematical tool for implementing the concept of neutrosophic inference systems, a consistent new algorithm of neutrosophic failure mode analysis has been presented, set up the neutrosophic risk priority numbers, and implement the new algorithm for inferencing and assessing the reliability and the stability of the system by using thirteen (IF-Then) rules derived from R1, R2, and R3.

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