TAKEHOME #3- Harmonic distortion diagnosis using fuzzy logic in fuzzy clips

I.PROPOSAL

The way that people think is inherently fuzzy. The way that we perceive the world cannot always be defined in true or false statements. Fuzzy logic allows for the members of a set to have degrees of membership. The number assigned to an object in the set is called its degree of membership in the set and it can value between 0 and 1.

The intention of this project is to use fuzzy logic in fuzzy clips to analyse,compare and diagnose harmonic distortion in power systems. Harmonic distortion may or may not create a problem for a power system. However, as harmonic levels increase, the likelihood of experiencing problems also increases. Typical problems include:

- malfunctioning of microprocessor-based equipment.
- overheating in neutral conductors, transformers or induction motors.
- deterioration or failure of power factor correction capacitors.
- erratic operation of breakers and relays.

Harmonics can sometimes be transmitted from one facility back through the utility's equipment to neighboring businesses, especially if they share a common transformer. This means harmonics generated in one system can stress utility equipment or cause problems in the neighboring system.Hence it is necessary to diagnose the level of harmonic distortion so that necessary actions can be taken to reduce it.

i.REFERENCES

- Bryan Klingenberg ,"A Time-Varying Harmonic Distortion Diagnostic Methodology Using Fuzzy Logic".

ii.GOALS

Harmonic distortion basically depends on two parameters-voltage and temperature. The voltage values can be between 0 to 10 and can fall in one of the following category- very low,low,medium,high and very high ; the temperature can be of any value between 30 to 100 degrees and can fall in any of the following categories- below normal,normal,very hot and over heating. Based on the voltage and temperature given by the user, the fuzzy clips program will output whether the harmonic distortion will be of problem to the power system or not. The inputs will be used to determine the fuzzy membership sets. **Mamdani method is used for fuzzification and centroid method will be used for defuzzification as given in the reference paper**.The harmonic voltage membership functions define anything below 0 as **very low**, anything from 0 to 5 as **low**, anything from 2.5 to 7.5 is **medium**, and anything from 5 to 10 is **high** and anything above 10 as **very high**. The temperature membership functions are triangular and define anything between 30 and 53 as **below normal** with below normal centered at 30 , anything between 30 and 76 is defined as **normal** with normal centered at 53 , anything between 30 and 76 is defined as **overheating** with overheating centered at 76 and anything greater than 76 as **very hot**. The following table is used for determining what the output should be(given in the reference paper):

Harmonic voltage	**Temperature**	**Output**
Very low	Below normal	No problem
Very low	Normal	No problem
Very low	Overheating	No problem
Very low	Very hot	Caution
Low	Below normal	No problem
Low	Normal	No problem
Low	Overheating	Caution
Low	Very hot	Possible problems
Medium	Below normal	No problem
Medium	Normal	Caution
Medium	Overheating	Possible problems
Medium	Very hot	Possible problems
High	Below normal	Caution
High	Normal	Possible problems
High	Overheating	Possible problems
High	Very hot	Imminent problems
Very high	Below normal	Possible problems
Very high	Normal	Possible problems
Very high	Overheating	imminent problems
Very high	Very hot	Imminent problems

iii.OUTCOME

The outcome will be a fuzzy clips program which can obtain input temperature and voltage in non fuzzy terms and display the output in fuzzy terms ,that is, whether the harmonic distortion generated will affect the power system or not. A few sample results will also be enclosed in the archive for reference.

TAKEHOME #3-REPORT

CODE LISTINGS

Shown below is the code used to implement the fuzzy logic discussed above in the proposal. A “.clp” file is also included in the archive for verifying the implementation of the code.

```
(deftemplate voltage ;;definition of fuzzy variable 'voltage'
0 10 ;universe
( (very_low (0 1)(1.5 0.5)(2.5 0) )
(low (0 0)(1.5 0.5)(2.5 1)(3.5 0.5)(5 0))
(medium (2.5 0)(3.5 0.5)(5 1)(6.5 0.5)(7.5 0))
(high(5 0)(6.5 0.5)(7.5 1)(8.5 0.5)(10 0))
(very_high (s 7.5 10))))


(deftemplate temperature ;;definition of fuzzy variable 'temperature'
30 100 ;universe
( (below_normal (30 1)(42.5 0.5)(53 0) )
(normal(30 0)(42.5 0.5)(53 1)(67.5 0.5)(76 0))
(over_heating(53 0)(67.5 0.5)(76 1)(88.5 0.5)(100 0))
(very_hot(76 0)(88.5 0.5)(100 1)))
)


(deftemplate warning ;;definition of fuzzy variable 'warnings'
0 10 ;universe
( (no_problem (0 0.5)(0.12 1)(0.25 0.5)(0.38 0) )
(caution(0.12 0)(0.25 0.5)(0.38 1)(0.5 0.5)(0.62 0))
(possible_problem(0.38 0)(0.5 0.5)(0.62 1)(0.75 0.5)(0.88 0))
(imminent_problem(0.62 0)(0.75 0.5)(0.88 1)(1 0.5)))
)


(defrule rule1
(voltage very_low)
(or(temperature below_normal)(temperature normal)(temperature over_heating))
=>
 (assert(warning no_problem)))

(defrule rule2
(voltage very_low)
(temperature very_hot)
=>
(assert(warning caution)))

(defrule rule3
(voltage low)
(or(temperature below_normal)(temperature normal))
=>
(assert(warning no_problem)))
```

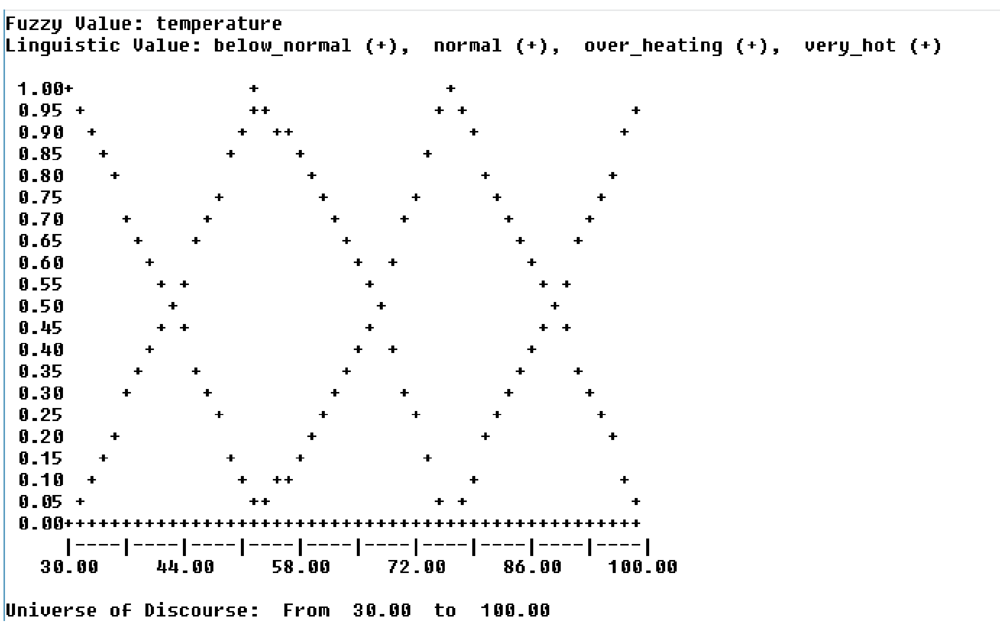
```
(defrule rule4
(voltage low)
(temperature over_heating)
=>
(assert(warning caution)))


(defrule rule5
(voltage low)
(temperature very_hot)
=>
(assert(warning possible_problem)))


(defrule rule6
(voltage medium)
(temperature below_normal)
=>
(assert(warning no_problem)))

(defrule rule7
(voltage medium)
(temperature normal)
=>
(assert(warning caution)))


(defrule rule8
(voltage medium)
(or(temperature over_heating)(temperature very_hot))
=>
(assert(warning possible_problem)))

(defrule rule9
(voltage high)
(temperature below_normal)
=>
(assert(warning caution)))


(defrule rule10
(voltage high)
(or(temperature normal)(temperature over_heating))
=>
(assert(warning possible_problem)))


(defrule rule11
(voltage high)
(temperature very_hot)
=>
(assert(warning imminent_problem)))
```

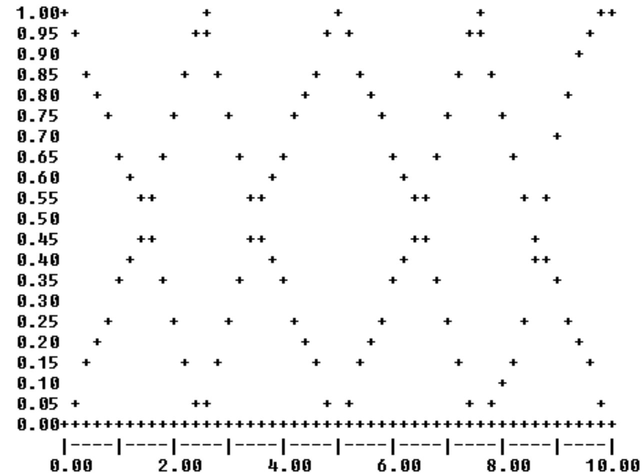
```
(defrule rule12
(voltage very_high)
(or(temperature below_normal)(temperature normal))
=>
(assert(warning possible_problem)))


(defrule rule14
(voltage very_high)
(or(temperature over_heating)(temperature very_hot))
=>
(assert(warning imminent_problem)))

;;get crisp input
(defrule getTemperatureandVoltage
   (declare (salience 100))
   =>
   (printout t "Enter temperature: " crlf)
   (bind ?t (read))
   (assert (crisptemp ?t))
(printout t "Enter voltage: "crlf)
(bind ?t (read))
(assert (crispvolt ?t)))

;;fuzzify the crisp inputs
(defrule FuzzifyTemperatureandVoltage
   (crisptemp ?a)
(crispvolt ?b)
   =>
(bind ?t1 (- ?a 0))
   (bind ?t2 (+ ?a 0))
(bind ?t3 (- ?b 0))
   (bind ?t4 (+ ?b 0))
   (assert (temperature (?t1 0) (?a 1) (?t2 0)))
(assert(voltage(?t3 0)(?b 1)(?t4 0))))


;;showing the  defuzzified output

(defrule answer
(declare(salience -100))
(warning ?aa)
=>
(plot-fuzzy-value t "*" 0 1 ?aa)
(printout t crlf "Harmonic Distortion is " (moment-defuzzify ?aa)crlf)
(if (< ?aa2 0.25)
then
(printout t "Harmonic distortion causes no problem" crlf))
(if (and(> ?aa2 0.25)(< ?aa2 0.5))
then
(printout t "caution,Harmonic distortion might cause problem" crlf))
(if (and(> ?aa2 0.5)(< ?aa2 0.75))
then
(printout t "possible problem might be caused by harmonic distortion" crlf))
```

```
(if (> ?aa2 0.75)
then
(printout t "Imminent problems,check system" crlf)))
```

DEVELOPMENT EFFORT

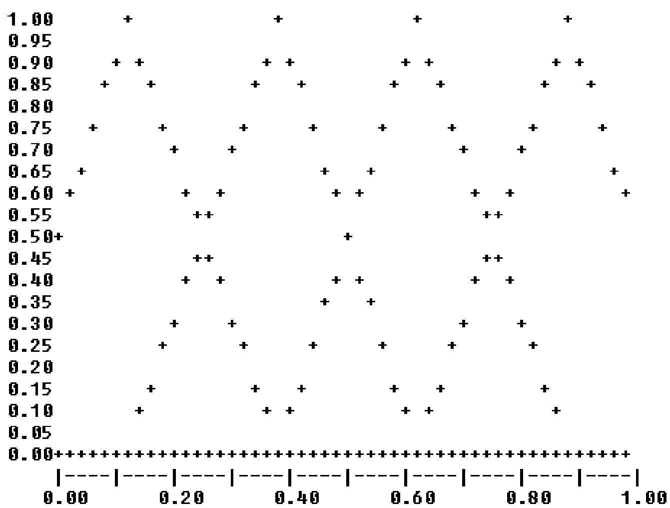
The development of the coding is from the information and the graph in the reference paper. First, we define two deftemplates for variables **voltage and temperature**-our harmonic distortion is dependent on these two variables.The membership function for voltage is a triangular function and it defines range for fuzzy terms-**very_low, low, medium, high and very high** and membership function for temperature is a triangular function and it defines range for fuzzy terms-**below_normal, normal, very_hot and over_heating**. Given below is the screenshot of the two deftemplates:





Universe of Discourse: From 0.00 to 10.00

Based on the two membership functions defined above we need to specify the type of warning and hence we create another deftemplate “**warning**” which defines fuzzy terms such as no_problem, caution, possible_problem, immediate_problem. The membership function used is triangular in nature. A plot of the deftemplate warning is provided below:



Next, several rules have been defined based on the table given in the reference paper, for example

```
If
(voltage is very_low)
And
(temperature is very_high)
Then
(warning is no_problem)
```

And several of these rules have been combined using **Or** condition in fuzzy clips to simplify the code even further as these rules are the defining elements of our program. Since we are obtaining a crisp input from the user ,we need to represent the crisp concept as a fuzzy set and hence singleton representation is used. For example if we need to represent 7 volts in fuzzy set then, **(voltage (7 0) (7 1) (7 0))** should do it; using this method both temperature and voltage which are obtained as crisp input from the user are fuzzified.The fuzzy inference method used is **mamdani** method. These fuzzified values are asserted to voltage and temperature deftemplates respectively and then the corresponding rules are fired and warning has some fuzzy output which is defuzzified using **center of gravity method**, whose formula is given by

$$X' = \frac{\int (x.f(x))dx}{\int f(x)dx}$$

The defuzzified output is the harmonic distortion caused in the system. This output is then checked in an if..then loop and based on its value we print whether it causes any problem and if so what level of problem. The pseudo-code for the if loop is as follows:

```
If(harmonic distortion < 0.25)
Then no problem
If(harmonic distortion > 0.25 && harmonic distortion <0.5)
Then caution
If(harmonic distortion > 0.5 && harmonic distortion < 0.75)
Then possible problem
If(harmonic distortion >0.75)
Then Imminent problem
```

RESULTS AND EXAMPLES

Example 1:

```
(load "D:/knowledge engg/fuzzy clips/code3final.clp")
FuzzyCLIPS> Defining deftemplate: voltage
Defining deftemplate: temperature
Defining deftemplate: warning
Defining defrule: rule1 +j+j
=j+j
=j+j
Defining defrule: rule2 =j+j
Defining defrule: rule3 +j+j
=j+j
Defining defrule: rule4 =j+j
Defining defrule: rule5 =j+j
Defining defrule: rule6 +j+j
Defining defrule: rule7 =j+j
Defining defrule: rule8 =j+j
=j+j
Defining defrule: rule9 +j+j
Defining defrule: rule10 =j+j
```

```
=j+j
Defining defrule: rule11 =j+j
Defining defrule: rule12 +j+j
=j+j
Defining defrule: rule14 =j+j
=j+j
Defining defrule: getTemperatureandVoltage +j
Defining defrule: FuzzifyTemperatureandVoltage +j+j
Defining defrule: answer +j
TRUE
FuzzyCLIPS> (reset)
FuzzyCLIPS> (run)
Enter temperature:(30-100)
30
Enter voltage:(0-10)
1

Harmonic Distortion is 0.1533204881181759
Harmonic distortion causes no problem
```

From the example above, we can see that for a voltage value of 1V(very_low) and temperature 30(low),we get harmonic distortion of 0.1533 (no_problem) which agrees with our rule set which is given in the proposal.Few more examples are given below which also agree with our defined set of rules.

Example 2:

```
(load "D:/knowledge engg/fuzzy clips/code3final.clp")
FuzzyCLIPS> Defining deftemplate: voltage
Defining deftemplate: temperature
Defining deftemplate: warning
Defining defrule: rule1 +j+j
=j+j
=j+j
Defining defrule: rule2 =j+j
Defining defrule: rule3 +j+j
=j+j
Defining defrule: rule4 =j+j
Defining defrule: rule5 =j+j
Defining defrule: rule6 +j+j
Defining defrule: rule7 =j+j
Defining defrule: rule8 =j+j
=j+j
Defining defrule: rule9 +j+j
Defining defrule: rule10 =j+j
=j+j
Defining defrule: rule11 =j+j
Defining defrule: rule12 +j+j
=j+j
Defining defrule: rule14 =j+j
=j+j
Defining defrule: getTemperatureandVoltage +j
```

```
Defining defrule: FuzzifyTemperatureandVoltage +j+j
Defining defrule: answer +j
TRUE
FuzzyCLIPS> (reset)
FuzzyCLIPS> (run)
Enter temperature:(30-100)
89
Enter voltage:(0-10)
8
Harmonic Distortion is 5.220327550813134
Imminent problems,check system
```

<u>Example 3:</u>

```
(load "D:/knowledge engg/fuzzy clips/code3final.clp")
FuzzyCLIPS> Defining deftemplate: voltage
Defining deftemplate: temperature
Defining deftemplate: warning
Defining defrule: rule1 +j+j
=j+j
=j+j
Defining defrule: rule2 =j+j
Defining defrule: rule3 +j+j
=j+j
Defining defrule: rule4 =j+j
Defining defrule: rule5 =j+j
Defining defrule: rule6 +j+j
Defining defrule: rule7 =j+j
Defining defrule: rule8 =j+j
=j+j
Defining defrule: rule9 +j+j
Defining defrule: rule10 =j+j
=j+j
Defining defrule: rule11 =j+j
Defining defrule: rule12 +j+j
=j+j
Defining defrule: rule14 =j+j
=j+j
Defining defrule: getTemperatureandVoltage +j
Defining defrule: FuzzifyTemperatureandVoltage +j+j
Defining defrule: answer +j
TRUE
FuzzyCLIPS> (reset)
FuzzyCLIPS> (run)
Enter temperature:(30-100)
44
Enter voltage:(0-10)
8
Harmonic Distortion is 0.5142361433838337
possible problem might be caused by harmonic distortion
```

Example 4:

```
(load "D:/knowledge engg/fuzzy clips/code3final.clp")
FuzzyCLIPS> Defining deftemplate: voltage
Defining deftemplate: temperature
Defining deftemplate: warning
Defining defrule: rule1 +j+j
=j+j
=j+j
Defining defrule: rule2 =j+j
Defining defrule: rule3 +j+j
=j+j
Defining defrule: rule4 =j+j
Defining defrule: rule5 =j+j
Defining defrule: rule6 +j+j
Defining defrule: rule7 =j+j
Defining defrule: rule8 =j+j
=j+j
Defining defrule: rule9 +j+j
Defining defrule: rule10 =j+j
=j+j
Defining defrule: rule11 =j+j
Defining defrule: rule12 +j+j
=j+j
Defining defrule: rule14 =j+j
=j+j
Defining defrule: getTemperatureandVoltage +j
Defining defrule: FuzzifyTemperatureandVoltage +j+j
Defining defrule: answer +j
TRUE
FuzzyCLIPS> (reset)
FuzzyCLIPS> (run)
Enter temperature:(30-100)
45
Enter voltage:(0-10)
5
Harmonic Distortion is 0.3063906704483581
caution,Harmonic distortion might cause problem
```

SUMMARY OF THE REPORT

This report presents a method to analyze harmonic distortion impact on system equipment using fuzzy logic in fuzzy clips. The examples generated indicate the potential of using fuzzy clips for studying complex systems and performing a meaningful evaluation and analysis of the impact of time-varying harmonic distortion on a power system.

FUTURE DEVELOPMENT

For future development we can develop a fuzzy system which takes into account the fundamental voltage variation as well as the variation of the third, fifth and seventh harmonics. We can analyze the different types of faults generated based on the level of harmonic distortion produced in the system.