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Linguistic Display of Status of System to Support Distribution Sub-Station Operator

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***Abstract*-- This paper presents a new method of analyzing the distribution system under uncertain variations in the loads. The measured load variation data collected from a practical radial distribution system have been modeled as Type-2 Fuzzy Sets, which represents the uncertain variations in the load. The developed Type-2 membership function models have been validated using Mambdani-FIS by computing the centroid values of voltages at each bus (Consequent) for the centroid values of Type-2 fuzzy set modeled as load at each bus (Antecedent) and these values are compared with voltages obtained by normal power flow solution for the centroid values of the load. Further the authors proposes a new Linguistic Display Aiding Tool for the Substation Operator, by displaying the status of Voltage Drops, Line Flows in each branches of the Feeder and Laterals Linguistically where the substation operator gets the display of the status in his local language. For which the authors uses a similarity measuring method between the standard type-2 fuzzy sets labeled with linguistic words and the Type-2 fuzzy sets of voltages at each bus or the voltage drops in each branches of the laterals or the losses in each line. The measures of uncertainty such as centroid, cardinality, fuzziness, Skewness and Variance of the IT2 FS of loads and voltages are computed. These are useful to compute two types of uncertainties associated with a word: intra-personal uncertainty and inter-personal uncertainty.**

***Index Terms*—Transformer-load-model, Interval Type-2 Fuzzy set, uncertainty, load duration curve, fuzzy Inference System, Similarity measure of Uncertainty.**

I. INTRODUCTION

An integral part of distribution automation is the real-time monitoring and control of distribution circuits to facilitate feeder analysis functions such as volt/var control, feeder reconfiguration and restoration, and demand-side management. To accomplish this task of real-time monitoring and control requires a distribution circuit state estimator tool which can provide real-time estimates of circuit states, i.e. bus voltages and line flows. A requirement of any distribution circuit state estimator is a load modeling (estimation) procedure which can provide real-time estimates of customer load demands. This is needed due to the limited availability of real-time measurements on distribution circuits. Previous load modeling techniques have generally been used for a system peak-type power flow analysis [7, 8]. Thus, they have largely ignored the normal variations in load demands that occur throughout the day. Another drawback of traditional load modeling procedures is their inability to provide a measure of uncertainty regarding its estimates. Kuo and Hsu [7] do propose a time-of-day dependent load modeling technique which makes use of fuzzy logic and transformer kVA.

Probabilistic modeling of random uncertainty focuses to a large extent on methods that use at least the first two moments of a probability density function (pdf)—the mean and the variance. To just use the first order moments would not be very useful, because random uncertainty requires an understanding of dispersion about the mean and this information is provided by the variance. In fuzzy logic (FL), we may view computing the defuzzified output of a type-1 FLS as analogous to computing the mean of a pdf. Just as variance provides a measure of dispersion about the mean and is almost always used to capture more about probabilistic uncertainty in practical statistical-based designs, FLS's also need some measure of dispersion to capture more about rule uncertainties than just a single number. Type-2 FL provides this measure of dispersion and seems to be as fundamental to the design of systems that include linguistic and/or numerical uncertainties that translate into rule uncertainties as variance is to the mean [11]. Application of fuzzy set theory in distribution system analysis can sharpen professional judgment and past experiences in planning, design and operations of distribution system. In distribution system, uncertainty in load can directly be taken into account with the help of the concepts from the fuzzy set theory. A special feature of this fuzzy set approach is that it enables us to deal with uncertain terms, such as load currents in a systematic manner. Furthermore, generally certain linguistic terms such as heavily loaded, lightly loaded, etc. are used to describe system loading conditions. Fuzzy set approach provides us not only with a meaningful and powerful representation of measurement uncertainties, but also with a meaningful representation of vague concepts expressed in natural language. The concept of type-2 FS was introduced by Zadeh [10] as an extension of the concept of an ordinary fuzzy set, i.e., a type-1 fuzzy set. Type-2 FS have grades of membership that are themselves fuzzy [7, 8]. A type-2 membership grade can be any subset in the primary membership; and, corresponding to each primary membership, there is a secondary membership (which can also be in) that defines the possibilities for the primary membership. A type-1 fuzzy set is a special case of a type-2 fuzzy set; its secondary membership function is a subset with only one element-unity.

In this paper modeling of the distribution transformer load variation for a day using the statistics and fuzzy sets is presented. A standard rural distribution transformer load variation that is uncertain which vary statistically over a period of 24-hour duration is modeled as fuzzy trapezoidal membership functions (Type-1). In a practical distribution system the upper and lower limits of membership function are uncertain. These membership functions are modeled as Type-2 fuzzy membership functions. Here a rural distribution feeder is considered as our test system, for which the current readings of the feeder are collected at the substation for a month. Total kVA load of the feeder for 31-days and 24-hrs is measured, from which the kVA loading at each node is obtained based on the kVA ratings of the respective transformers at that nodes. A trapezoidal membership function (Type-1) is modeled for each transformer rating for one-day; like that we get 31-trapezoidal membership functions (Type-1) for one-month. The trapezoidal membership functions (Type-1) for one-month together is represented as Interval Type-2 Trapezoidal membership function, so that the uncertainties in the load variations at the transformer is taken into consideration. We use type-2 fuzzy logic systems in which the antecedent or consequent membership functions are type-2 fuzzy sets. The knowledge used to construct rules in a fuzzy logic system (FLS) is uncertain. This uncertainty leads to rules having uncertain antecedents and/or consequents, which in turn translates into uncertain antecedent and/or consequent membership functions. The mappings between input and output data pairs are uncertain due to load dynamics and exact unknown line-length in distribution system [3, 5, and 11]. These linguistic and numerical data uncertainties lead type-1 fuzzy logic systems to perform poorly. However, type-2 fuzzy sets are able to handle these uncertainties.

I. Introduction to Type-2 Fuzzy sets

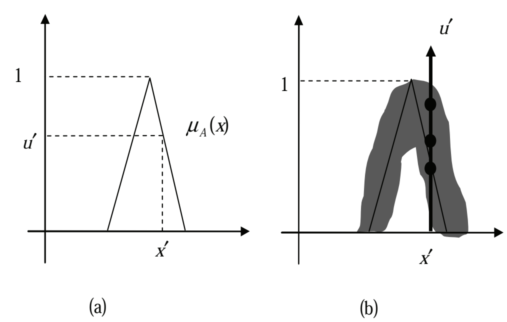

Figure 1-(a) An example of the general fuzzy set; (b) an example of the type-2 fuzzy set.

Figure 1 depicts the examples of the general fuzzy set and the type-2 fuzzy set. In Fig. 1-(a), at a specific value of *x*, say x', the membership function has a single value in the general fuzzy set. By contrast, the membership function takes on values wherever the vertical line intersects the blur in Fig. 1-(b). Those values need not all is weighted the same; hence, an amplitude distribution is assigned to all of those points. According to all $x \in X$, a three-dimensional membership function, a type-2 membership function is used to characterize a type-2 fuzzy set.

The definitions of type-2 fuzzy sets

According to [11], type-2 fuzzy sets are defined as follows. For the sake of simplicity, the universe of discourse is assumed as a finite set, although the definition can be applied for infinite sets.

A type-2 fuzzy set, $\tilde{A}$, is characterized by a type-2 membership function $\mu_{\tilde{A}}(x,u)$, where X is the universal set, $x \in X$ and $u \in J_x \subseteq [0,1]$; that is,

$$\tilde{A} = \{((x,u), \mu_{\tilde{A}}(x,u)) \mid \forall x \in X, \forall u \in J_x \subseteq [0,1]\}$$

,

where $0 \le \mu_{\tilde{A}}(x,u) \le 1$. $\tilde{A}$ can also be expressed as

$$\tilde{A} = \sum_{x \in X} \sum_{u \in J_x} \mu_{\tilde{A}}(x,u)/(x,u),\ J_x \subseteq [0,1],$$

where $\sum\sum$ indicates the union over all admissible *x* and *u*.

Accordingly, at each value of *x*, say $x = x'$,

$$\mu_{\tilde{A}}(x=x', u) \equiv \mu_{\tilde{A}}(x') = \sum_{u \in J_{x'}} f_{x'}(u)/u, \text{for } u \in J_{x'} \subseteq [0,1] \text{ and } x' \in X$$

,

where $\mu_{\tilde{A}}(x)$ represents the secondary membership function.

Moreover, because the membership grades of type-2 fuzzy sets are the values of type-1 fuzzy sets, performing operations like union and intersection on type-2 fuzzy sets is like performing t-conorm and t-norm operations between type-1 fuzzy sets. Computations used with the Interval type-2 fuzzy sets [11, 14] are manageable. All of the results that are needed to implement an Interval type-2 fuzzy set (IT2 FS) can be obtained using Type-1 fuzzy sets (T1 FS) mathematics. An Interval type-2 fuzzy set is a set with all the secondary membership values equal to one.

The Jaccard similarity measure for IT2 FSs

Given a vocabulary consisting of N words with their associated IT2 FS$\tilde{B}$, the goal is to find the $\tilde{B}$ which closely resembles Ã, for which the similarity between two IT2 FS's is used. In the literature [9], Jaccard similarity measure is the most efficient method of measuring the similarity between the two IT2 FS's, so, the authors also adopt the same here.

Hence, consider two type-2 fuzzy sets $\tilde{A}$ and $\tilde{B}$, such that

$$\tilde{A} = \sum_{x \in X} \mu_{\tilde{A}}(x)/x = \sum_{x \in X} [\sum_{u \in J_x^u} f_x(u)/u]/x,\ J_x^u \subseteq [0,1]$$

,

and

$$\tilde{B} = \sum_{x \in X} \mu_{\tilde{B}}(x)/x = \sum_{x \in X} [\sum_{w \in J_x^w} g_x(w)/w]/x,\ J_x^w \subseteq [0,1]$$

.

$S_j(\tilde{A}, \tilde{B}) =$

(1)

(1)

$$\frac{\int_X \min(\bar{\mu}_{\tilde{A}}(x) + \bar{\mu}_{\tilde{B}}(x))dx + \int_X \min(\bar{\mu}_{\tilde{A}}(x) + \bar{\mu}_{\tilde{B}}(x))dx}{\int_X \max(\bar{\mu}_{\tilde{A}}(x) + \bar{\mu}_{\tilde{B}}(x))dx + \int_X \max(\bar{\mu}_{\tilde{A}}(x) + \bar{\mu}_{\tilde{B}}(x))dx}$$

Where $\bar{\mu}_{\tilde{A}}$ and $\bar{\mu}_{\tilde{B}}$ are the membership values of **Ã and $\tilde{B}$** IT2FS's.

Transformer Load Modeling

(3)

In this section the load modeling of different rated transformers that are connected to the rural distribution feeder is considered [7, 8]. Here we use a technique to generally allocate telemeter substation power flows (or other metered flows) to various load points by using ratios obtained from connected transformer capacities.

$$P_i = P_m \left(\frac{TC_i}{\sum_{i=0}^{n} TC_i}\right)$$

(2)

For example, where P_i = real power demand at node I,

P_m = real power flow metered at node m,

TC_i = transformer capacity at node i, and 'n' represents the number of nodes served by power flowing through node *m.*

Fuzzy Load Model (Type-1)

If x_i where i=1,2,3…..n (n<30) be the empirical per unit load data for (a) Residential (b) Commertial and (c) Industrial then the Trapezoidal and Triangular fuzzy number [2] parameters are

$$l_1 = min(x_i)$$

$$\left.\begin{aligned} p_1 &= min(x_i) - \frac{E(x)-\min(x_i)}{2} \\ p_2 &= E(x) + \frac{\max(x_i) - E(x)}{2} \\ r_2 &= max(x_i) \end{aligned}\right\} \qquad (3)$$

Where, E(x) is the expected value of load from the load duration curve of one day.

Interval Type-2 Fuzzy membership function

If x_i where i=1,2,3…..n (n<30) be the empirical per unit uncertain load data for Rural distribution system, then the Triangular fuzzy number (Dotted) will have a triangular $\underline{FOU}$ (lower foot-print-of-uncertinity) and a trapezoidal $\overline{FOU}$ (upper foot-print-of-uncertinity) with the following membership functions. So, this type of load variation can be modeled using an Interval type-2 fuzzy membership function [3] as discussed in the previous section.

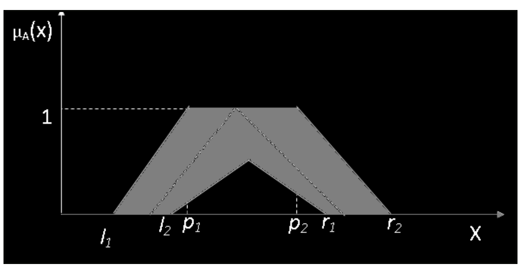

Fig-2: Type-2 fuzzy set trapezoidal upper membership function and lower triangular membership function

$$\underline{\mu(x)} = \underline{FOU(A)} = \begin{cases} 0 & x<l_2 \\ \frac{x-l_2}{p_2-l_2} & x \le \frac{r_1(p_2-l_2)+l_2(r_1-p_1)}{(p_2-l_2)+(r_1-p_1)} \\ \frac{r_2-x}{r_2-p_2} & x > \frac{r_1(p_2-l_2)+l_2(r_1-p_1)}{(p_2-l_2)+(r_1-p_1)} \\ 0 & x > r_2 \end{cases} \qquad (4)$$

$$\overline{\mu(x)} = \overline{FOU(A)} = \begin{cases} 0 & x<l_1 \\ \frac{x-l_1}{p_1-l_1} & l_1 \le x < p_1 \\ 1 & p_1 \le x < p_2 \\ \frac{r_2-x}{r_2-p_2} & p_2 < x < r_2 \\ 0 & x > r_2 \end{cases} \qquad (5)$$

Where 'x' is the active and reactive power load, the corresponding membership function values μ(x) can be obtained for the lower and upper foot-print-of-uncertainties (FOU) as given by the above equations.

Representation of load variation by type-2 fuzzy sets

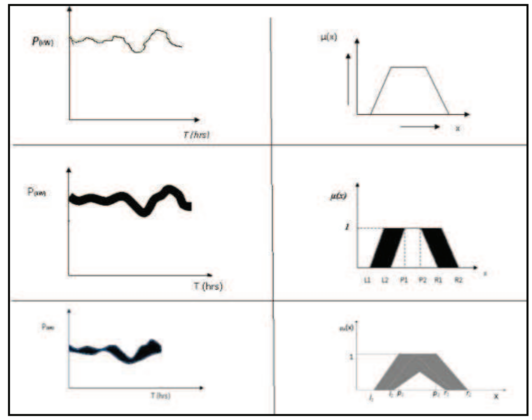

Fig-3: Represents load duration curves (left) replaced by a Type-2 fuzzy set with n-number of Type-1 fuzzy sets (row 2 and 3 in column 2).

II. INTERVAL TYPE-2 FUZZY INFERENCE SYSTEM

The membership functions are modeled by classifying the each load variation with linguistic variables Least, Very Very Small, Very Small, Small, High Medium, Medium, Low Medium, Large, Very Large, Very Very Large, Maximum, Extreme. The fuzzy rules permit expressing the available knowledge about the relationship between antecedent and consequents. To express this knowledge completely we normally have several rules, grouped to form what it is known a rule base, that is, a set of rules that express the known relationships between antecedent and consequents. For example the Rule: If Load is **Very large** then Voltage is **Very Small** this is for Single-Antecedent and Single-Consequent case. If Load is **large** and line-length is **small** then Voltage-drop is **Medium**. This is for Two-Antecedent and Single-Consequent case. Similarly other rules can be framed based on the distribution system considered. The developed type-2 FIS will have the sets of rules which can be framed based on the inputs (Load data) and the outputs (Voltage at each bus). The proposed algorithm is flexible for modification of inference rules. The program has been implemented in MATLAB R2007b.

A. Antecedent and Consequent membership functions [12,13]

Step-1: Initially the data (Active and Reactive power readings of the rural feeder for 48-samples per day, line data, load data and line lengths)is collected from the substation.

Step-2: Perform the power flow solution for the 31 days of a month with 48-samples of load data for each day, for all the 37-load points of the feeder.

Step-3: From the load data collected from step-1, using Eq.(4) and Eq.(5) the Interval Type-2 Fuzzy anticident membership function is determined.

Step-4: From the Computed feeder voltage-drops from step-2, using Eq.(4) and Eq.(5) the Interval Type-2 Fuzzy consiquient membership function is determined.

Step-6: Fuzzy inference rules are framed with two-inputs (Loads and Line-length) and one-output (Voltage drops) as shown in Table-1.

Step-7: A mamdani fuzzy inference system is used to relate the antesident and consiquent Interval Type-2 membership functions.

Step-8: Thus, an input-output relation Graph is obtained for the upper and lower Trapezoidal Interval Type-2 membership functions, Which can give information about the uncertain relationship that exists in practical distribution system between the loads, line-lengths and feeder voltage drops.

Implementation

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_2 \\ I_3 \\ I_4 \end{bmatrix}$$

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = I_2 \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} + I_3 \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix} + I_4 \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

Where $I_2 = (P_2 - j^*Q_2)/V_2^*$ Similarly I_3 and I_4.

$$\begin{bmatrix} V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} Z_1 \\ Z_1 \\ Z_1 \end{bmatrix} I_2 + \begin{bmatrix} Z_1 \\ Z_1 + Z_2 \\ Z_1 + Z_2 \end{bmatrix} I_3 + \begin{bmatrix} Z_1 \\ Z_1 + Z_2 \\ Z_1 + Z_2 + Z_3 \end{bmatrix} I_4$$

All the type-2 fuzzy load currents can be added using the above equation to calculate the type-2 bus voltages at bus-2,3and4 respectively. Z is a function of (R + j*X) Ohms/Km and length of the feeder in Kilometers. In the above equation if I_2, I_3, and I_4 are Type-2 Trapezoidal fuzzy membership functions, than the voltages obtained are also the Type-2 Trapezoidal fuzzy membership functions.

III. MEASURES OF UNCERTAINTY

The measures of uncertainties [16] of Type-2 Fuzzy numbers such as Fuzziness, Variance, Skewness, Cardinality and Centroid for the obtained outputs from the fuzzy inference system gives information in the uncertain voltage variations with the uncertain variation in the load. These uncertainty measures for IT2 FSs each are represented as interval, and the length of the interval is an indicator of uncertainty. The larger (smaller) the interval, the more (less) the uncertainty. The measures may also be used to measure the similarity between two IT2 FSs. Cardinality is the most representative uncertainty measure for an IT2 FS: its center is a representative intra-personal Uncertainty measure, and its length is a representative inter-personal uncertainty measure [12]. Centroid is a very important characteristic for IT2 FSs: its center can be used in ranking, and its length is a representative inter-personal uncertainty measure. Further the similarity measures of interval Type-2 fuzzy sets will help in identifying the **obtained output word** from the Type-2 FIS (Linguistic label), e.g., voltage in our case similar to the desired word (Linguistic label). The substation operator could take an appropriate decision with the obtained output results from Type-2 FIS. There are many similarity measures for Interval Type-2 Fuzzy Sets (IT2 FSs) in literature, Jaccard similarity measure is the most efficient method of measuring the similarity between the two IT2 FS's, so, and the authors also adopt the same here.

The developed Interval Type-2 Fuzzy Inference System (IT FIS) helps the system planner to get the overview of the state of the system for a longer duration (studied data for more than one-month), from the obtained IT2 FS's of voltages at each bus, line-voltage-drops, power flows and losses in each lines. Whereas at an instant of time of a day (snap-shot) for a particular loads at each of the bus, the developed IT2 FIS gives a point on the Trapezoidal IT2 FS (Example: Voltage), if the point falls numerically within the 12-test membership functions in Table- 1 the Jaccard similarity measure will produce a number which is less than one, like this the similarity measure value is calculated by using eq.(1). Table-3 is produced with the standard membership functions along columns specified by 12-linguistic words, and the rows are the number of buses that are present in the considered distribution system. The highest value of number in the row of Table-3 which is given in the last column of Table-3, will display the status of the system with a linguistic word. This is depicted in Table-2 for a particular snap-shot of the day.

Table-1: Standard Linguistic Words which are modeled as IT2 FS.

Word Number	Linguistic Words
1	Alarm
2	Very Very
3	Very Small
4	Small
5	High Medium
6	Medium
7	Low Medium
8	Large
9	Very Large
10	Very Very
11	Maximum
12	Good

Table-2: Linguistic-word which indicates the status of the system by Jaccard similarity measure of the obtained IT2 FS from the FIS with standard Linguistic Words.

Bus Number	Linguistic Words	Word Number	Jaccard Similarity Number
1	Low Medium	7	0.2935
2	Large	8	0.4578
3	Good	12	0.4276
4	Low Medium	7	0.2798
5	Large	8	0.268
6	Maximum	11	0.37
7	Good	12	0.3075
8	Good	12	0.3415
9	Good	12	0.4188
10	Large	8	0.2603
11	Large	8	0.2816
12	Large	8	0.3607
13	Very Large	9	0.3472
14	Good	12	0.4447
15	Very Large	9	0.3284
16	Very Very Large	10	0.3386
17	Very Very Large	10	0.4219
18	Very Very Large	10	0.4837
19	Very Very Large	10	0.4152
20	Maximum	11	0.3282
21	Maximum	11	0.3661
22	Good	12	0.353
23	Good	12	0.3091
24	Good	12	0.4184
25	Large	8	0.3613
26	Large	8	0.3441
27	Very Large	9	0.3146
28	Good	12	0.4442
29	Very Very Large	10	0.3398
30	Very Very Large	10	0.4218
31	Very Very Large	10	0.484
32	Very Very Large	10	0.4113

33	Good	12	0.3119
34	Good	12	0.3974
35	Good	12	0.4186
36	Good	12	0.3092
37	Good	12	0.4188

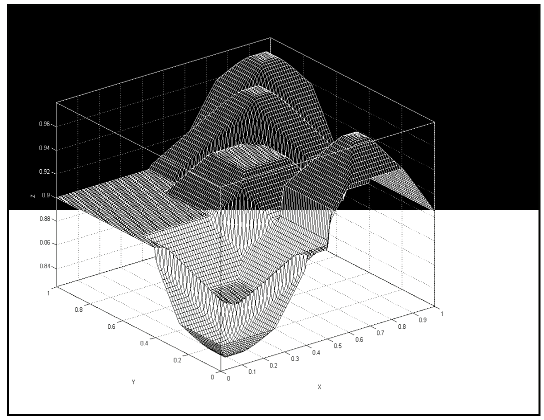

Fig-4: Represents the uncertain interval relationship between one-input (load variations) and one-output (bus voltages) membership functions

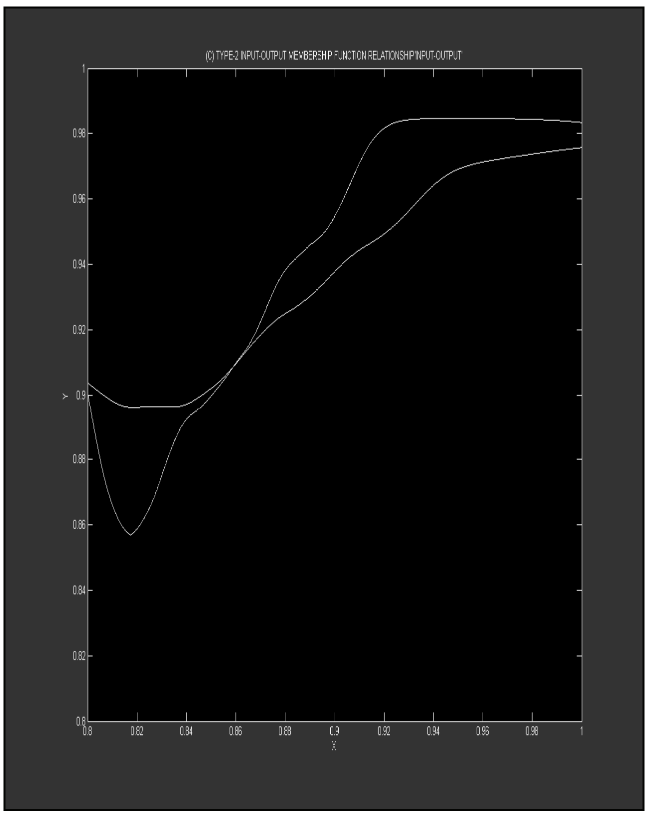

Fig-5: Represents the uncertain interval relationship between one-input (load variations), the second-input line-length uncertainty and output (bus voltages) membership functions

IV. RESULTS AND DISCUSSIONS

The uncertain input-output relationship revels the variation in the voltages with the variation in the load for an interval of values, these input-output relationship functions can be used to train the neural network learn the functions. The developed IT2 FIS can also be used for on-line studies, if the data from SCADA is synchronized with the developed program. Fig-5 represents the IT2 membership functions of losses in each branch, fig-6 represents the test membership function which are used for similarity measure with the voltage-drop and voltage membership functions, fig-7 and fig-8 represents the voltages and load s at each buses. The load at the substation is considered as zero, so the voltage at the substation is obtained as 1.0 p.u. so no membership functions are mentioned in the fig-7. Tables-3(Appendix) gives the Jaccard similarity measure values between the IT2FS of each branch voltage drop with the IT2FS of linguistic word. Also, the program is going to display, the branches where the voltage-drop is predominant and where there is less voltage-drop, so, at the substation the operator is able to view the status of each line with the linguistic label displays on the screen such as (small, considerable amount, high, medium,…..etc). By the above mentioned procedure it is also possible to find the status of bus-voltages Line-Currents and Power-Flows. The developed IT2 FIS has been validated by finding the centroid values of the output voltage membership functions with the resultant voltage obtained from the normal power-flow solution as mentioned by the procedure in section-III-B by taking the centroid values of the input load membership function.

APPENDIX

Word / Branch Number	Alarm	Very Very Small	Very Small	Small	High Medium	Medium	Low Medium	Large	Very Large	Very Very Large	Maximum	Good	Jaccard Similarity Number
1	0	0	0.0124	0.0007	0.0249	0.117	0.2158	0.2935	0.1317	0.0124	0	0	0.2935
2	0	0	0	0	0	0.0577	0.0837	0.4578	0.2149	0.098	0.0022	0	0.4578
3	0	0	0	0	0	0	0	0	0	0.0106	0.1144	0.4276	0.4276
4	0.0367	0.101	0.2798	0.2188	0.1358	0.13	0.0669	0.0802	0.0309	0.0023	0	0	0.2798
5	0	0.0183	0.2678	0.268	0.2527	0.2277	0.1078	0.1245	0.0528	0.0119	0	0	0.268
6	0	0	0	0	0	0.0241	0.0079	0.1225	0.1172	0.37	0.1729	0.0311	0.37
7	0	0	0	0	0	0.0082	0	0.0313	0.0336	0.3075	0.286	0.1038	0.3075
8	0	0	0	0	0	0	0	0	0	0	0.0506	0.3415	0.3415
9	0	0	0	0	0	0	0	0	0	0.0126	0.1229	0.4188	0.4188
10	0	0.0121	0.2368	0.258	0.2603	0.2484	0.1188	0.1297	0.0557	0.0144	0	0	0.2603
11	0	0.0048	0.1827	0.2306	0.254	0.2816	0.1399	0.1396	0.0596	0.0191	0	0	0.2816
12	0	0	0.0545	0.0651	0.1179	0.3607	0.2575	0.2011	0.0799	0.0431	0.0017	0	0.3607
13	0	0	0.0418	0.0422	0.0851	0.3472	0.284	0.2208	0.0884	0.0493	0.0029	0	0.3472
14	0	0	0	0	0	0	0	0	0	0	0.0687	0.4447	0.4447
15	0	0	0.0183	0.0067	0.0297	0.2416	0.3284	0.298	0.1262	0.0683	0.0095	0	0.3284
16	0	0	0.0116	0.0021	0.0191	0.2026	0.3055	0.3386	0.148	0.0766	0.0136	0	0.3386
17	0	0	0.0033	0	0.0056	0.1448	0.2136	0.4219	0.1998	0.0935	0.0237	0	0.4219
18	0	0	0	0	0	0.0989	0.1252	0.4837	0.278	0.1195	0.0376	0.0009	0.4837
19	0	0	0	0	0	0.067	0.0664	0.4152	0.3517	0.1647	0.0597	0.0036	0.4152
20	0	0	0	0	0	0.0463	0.0344	0.2711	0.3282	0.2463	0.0929	0.0099	0.3282
21	0	0	0	0	0	0.0267	0.0103	0.1389	0.1375	0.3661	0.159	0.0266	0.3661
22	0	0	0	0	0	0.01	0	0.0397	0.0399	0.353	0.2838	0.0886	0.353
23	0	0	0	0	0	0.003	0	0.0108	0.0131	0.1581	0.3091	0.1931	0.3091
24	0	0	0	0	0	0	0	0	0	0.0127	0.1233	0.4184	0.4184
25	0	0	0.0643	0.0814	0.1409	0.3613	0.2414	0.1908	0.0758	0.0396	0.0011	0	0.3613
26	0	0	0.041	0.0404	0.0828	0.3441	0.2837	0.2207	0.088	0.0483	0.0024	0	0.3441
27	0	0	0.0321	0.0236	0.0576	0.3146	0.3101	0.2454	0.0998	0.0562	0.0048	0	0.3146
28	0	0	0	0	0	0	0	0	0	0	0.0685	0.4442	0.4442
29	0	0	0.0114	0.002	0.0188	0.2013	0.3043	0.3398	0.1485	0.0768	0.0136	0	0.3398
30	0	0	0.0033	0	0.0056	0.1448	0.2137	0.4218	0.1998	0.0934	0.0237	0	0.4218
31	0	0	0	0	0	0.0983	0.1241	0.484	0.2791	0.1199	0.0377	0.0009	0.484
32	0	0	0	0	0	0.0664	0.0655	0.4113	0.3526	0.1658	0.0601	0.0037	0.4113
33	0	0	0	0	0	0.0026	0	0.0095	0.0116	0.1456	0.3119	0.2014	0.3119
34	0	0	0	0	0	0.0151	0.0013	0.0673	0.0593	0.3974	0.2449	0.0576	0.3974
35	0	0	0	0	0	0	0	0	0	0.0126	0.1231	0.4186	0.4186
36	0	0	0	0	0	0.003	0	0.0108	0.0131	0.1579	0.3092	0.1932	0.3092
37	0	0	0	0	0	0	0	0	0	0.0126	0.1229	0.4188	0.4188

Table-3: ***Voltage Drop*** in each branch is indicated by the JACCARD similarity MATRIX with the ***Rows as Branches*** and ***Columns as the Linguistic words*** along the Branches of the Practical Radial Distribution System

V. CONCLUSION

From the load data measured from the substation the Interval Type-2 Fuzzy Set (IT2 FS) of all the load buses are modeled. Consequent voltage IT2 FS is obtained by performing the power flow solution for 48 samples in a day and for 31-days of a month. Mamdani Interval Type-2 Fuzzy Inference System is developed, relationship between the load and voltage variations at each bus of the system can be used to find the voltage at each bus for a particular load at that bus. Once the consequent membership functions (IT2 FS's Voltages at each bus- **Ã**) are obtained for a particular IT2 FS's load, it is possible to map the IT2 FS **Ã** into a Word (Linguistic label). Given a standard vocabulary consisting of N words with their associated IT2 FS $\tilde{B}$, the goal is to find the Ã which closely resembles $\tilde{B}$, for which the similarity between two IT2 FS's is used. Jaccard similarity measure is the most efficient method of measuring the similarity between the two IT2 FS's, so, the authors also adopt the same here. The validity of the modeled IT2 FS of loads and the voltages have been verified by taking the centroid values of IT2 FS loads at each bus and performed the power-flow solution to find the centroid values of IT2 FS voltages at each bus. The measures of uncertainty of IT2FS have been computed. These uncertainty measures for IT2 FSs each are represented as interval, and the length of the interval is an indicator of uncertainty. The larger (smaller) the interval, the more (less) the uncertainty. The measures may also be used to measure the similarity between two IT2 FSs. The developed power-flow solution method can be used for Fault analysis, Contingency analysis, SMART GRID with bulk amount of uncertain data.

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