POWER QUALITY ENHANCEMENT BY ANALYSIS OF VOLTAGE SAG AND SWELL USING FUZZY LOGIC TECHNIQUE

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ABSTRACT : Power quality can be represented as the variation of voltage, current and frequency in a power system. Power quality (PQ) requirement is one of the most important issues of the power companies and their consumers. With the increased use of power electronic devices, customers have become more consideration on electric Power quality. Power quality problem encompass a wide range of disturbances such as voltage fluctuations like voltage sag and swell, notch, spine transient analysis using a variety of techniques. Power quality estimation is one of the important features which is automatically detected. power quality disturbances classification which requires the use of artificial intelligence techniques. In this paper, short-term application of fuzzy expert system voltage disturbances including voltage sag, swell and interrupts classification are discussed. Fuzzy expert system has been developed to set the input and output of the fuzzy rules. The system is designed to detect and the three types of short duration voltage disturbances classification.

Keywords- power quality, fuzzy control, fuzzy expert systems, feature extraction, membership function.

1. INTRODUCTION

Power quality problems and the problems arising are the consequences of the increasing use of solid state switching devices, nonlinear, power electronic switch load and electronic load. The advent of high power semiconductor switches in widespread use, distribution, and transfer leaves non-sinusoidal current [1]. Electronic load causes voltage distortion, harmonic distortion. Power quality problems can cause the onset of function systems equipment sensitive equipment, computer data loss and memory MAL function, such as computers, programmable logic devices [PLC] control, and the protection and relay devices [1].

A voltages sag or voltage dip is a short duration reduction in rms voltage which can be caused by a short circuit, overload or starting of electric motors. A voltage sag happens when the rms voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute. Some references define the duration of a sag for a period of 0.5 cycle to a few seconds, and longer duration of low voltage would be called a "sustained sag". Voltage swell is the opposite of voltage sag. Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system. Voltage swell happens for a period of 0.5 cycles to a minute, and if it last for longer time it is called sustained swell.

Voltage sag most widely spread of power quality problems that affect the distribution system, especially industry, which involves the loss can reach very high values. Short and shallow voltage dips can produce the entire industry out of school. In general, it is possible to consider the voltage dip as a source 10~90% power quality issues. The main reason is the breakdown voltage dips and short circuit, lightning and surge currents. In overhead distribution systems lightning is main cause of Voltage sag, with approximate incidence of about 50% of the cases [2].

To minimize power quality disturbances and to device suitable corrective and preventive measures, efficient detection and classification techniques are required in the emerging power systems. Classification of power quality disturbances based on the visual inspection of waveforms by human operators is laborious and time consuming. Moreover, it is not always possible to extract important information from simple visual inspection [2]. The classification of PQ disturbances in electric power systems has become an important task for proper developing and designing the preventive and corrective measures.

Artificial intelligence emerged as a computer science discipline in the mid 1950s. Since then, it has produced a number of powerful tools, many of which are of practical use in engineering to solve difficult problems normally requiring human intelligence. In this paper we have used Fuzzy Logic Systems to classify Voltage Sag, Swell, and Interruption [2] [3].

Fuzzy controllers are very simple and it is a new addition to control theory. They consist of an input stage, a processing stage, and an output stage. Its design philosophy differ from all previous methods by containing dexterous knowledge in controller design. These FLC are attractive choice where specific mathematical modeling formulas are not possible. It has good control robustness as compare to traditional control scheme. It modifies an dexterous knowledge based control strategy into automatic control strategy in essence [3].

A mamdani type Fuzzy Logic Controller is used in this study with max-min interference method which performs the function in four stages as shown in Fig. 1.

(1) Fuzzification

(2) Rule Base

(3) Inference Mechanism
(4) Defuzzification

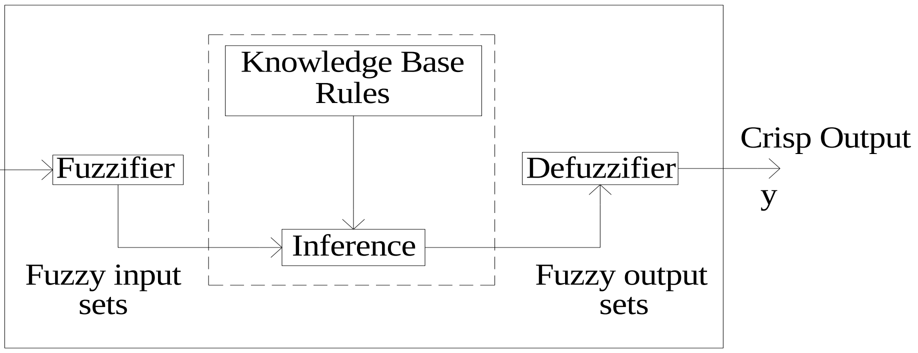

Fig. 1 Fuzzy Controller Architecture

Fuzzification is the process of changing real scalar value into a fuzzy value which is achieved with the different types of fuzzifiers. (membership functions). Rule Base system are used as a way to store and manipulate knowledge to interpret information in a useful manner. They are used in AI. Fuzzy Inference system (FIS) is a system that uses fuzzy set theory to map inputs (*features* in the case of fuzzy classification) to outputs (*classes* in the case of fuzzy classification).
Defuzzification is the process of producing a quantifiable result in Crisp logic, given fuzzy sets and corresponding membership degrees. It is the process that maps a fuzzy set to a crisp set.

2. THE PROPOSED FUZZY EXPERT SYSTEM, PREPROCESSING AND EXTRACTION OF FEATURES

The proposed fuzzy-expert system is designed to classify short duration voltage disturbances defined as instantaneous and momentary sag, swell and interruption, as shown in Fig.2 [3]. In the study, the disturbance data are obtained from PQ monitoring in which the monitoring software by default has three different sampling frequencies of 0.4 kHz (128 cycle), 1.6 kHz (32 cycle) and 6.4 kHz (8 cycles) and each frame has 1024 samples.

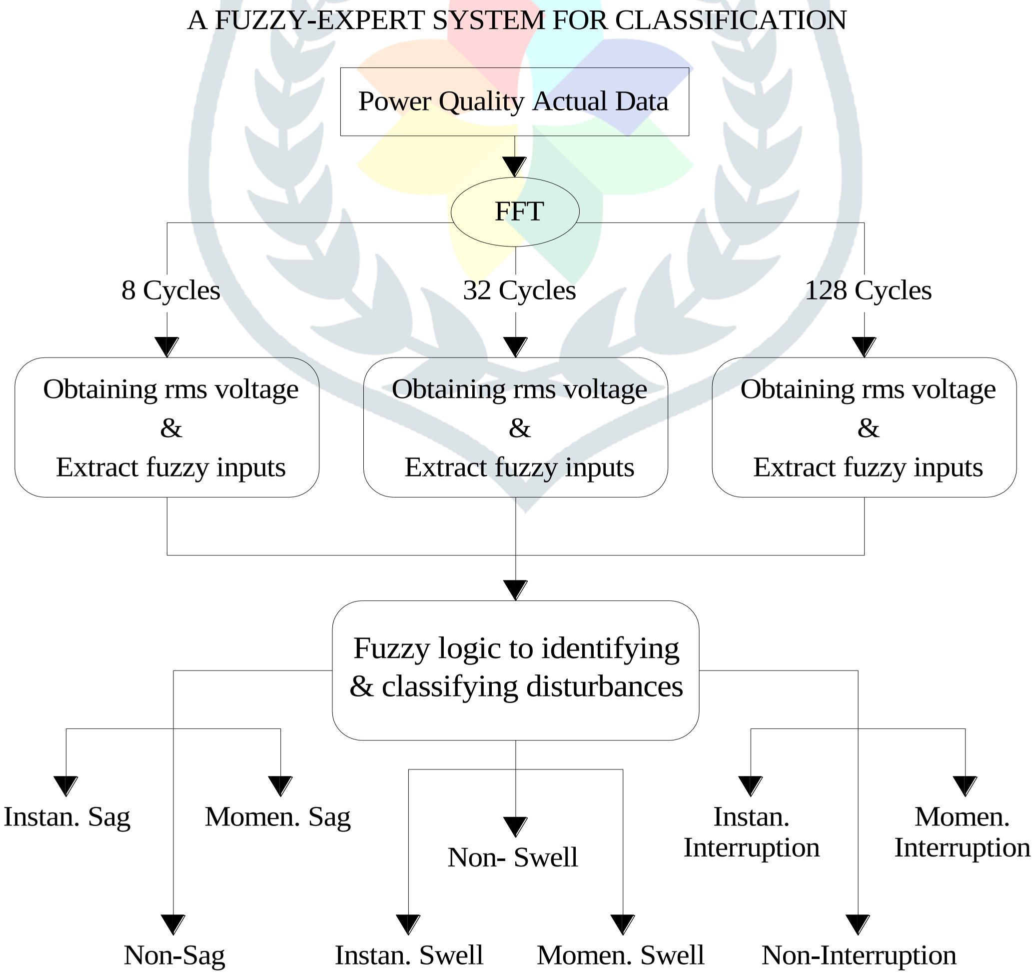

Fig. 2 Design of the proposed fuzzy-expert system

To process the raw disturbance data so as to extract features of the various disturbances, preprocessing of the disturbance signals is required. Initially, fast Fourier transform analysis is used to separate the 8, 32 and 128 cycle waveforms. Then root mean square (rms) method is applied by first approximating the fundamental frequency profile of actual voltage waveform and determining the maximum and minimum voltage magnitudes. An advantage of this method is its simplicity, fast calculation and less requirement of memory because rms voltage can be stored periodically instead of per sample [4].

3. FUZZY LOGIC INPUTS AND OUTPUTS

The Mamdani-type fuzzy system with five inputs and three outputs has been considered in the proposed fuzzy-expert system. The five inputs include maximum voltage in p.u (Max-V), sag duration in second (Sag Durat), swell duration in second (Swell Durat), transient duration in second (Tran Durat) and minimum voltage in p.u (Min-V) [5]. The maximum voltage has been chosen as a fuzzy input variable so as to classify instantaneous and momentary swell whereas the minimum voltage is for differentiating between interruption and voltage sag.

The sag duration is used as an input variable for classifying instantaneous and momentary sag whereas the swell duration is used to classify swell disturbance to instantaneous and momentary swell. The transient duration is chosen as a fuzzy input for distinguishing between instantaneous swell and impulsive transient disturbance [5]. The three FL outputs are Output1, Output2 and Output3 in which Output1 is designated for classifying instantaneous sag, non-sag and momentary sag, Output2 for classifying instantaneous swell, non-swell and momentary swell, and Output3 for classifying instantaneous interruption, non-interruption and momentary interruption [6].

4. MEMBERSHIP FUNCTIONS

The input and output variables are represented by the most common shape of membership functions which are either in trapezoidal or triangular forms and bell curves are also used., but the shape is less important than no of curves. The range of input variables and thresholds are chosen in accordance with the respective disturbance definition as defined in the IEEE Std. 1159-1995. Table 1 and 2 shows the fuzzy sets for input, output variable [7] [8].

TABLE 1: FUZZY SETS DEFINED FOR THE INPUT VARIABLES

Membership Function	**Input 1: Maximum voltage (p.u.)**	**Input 2: Sag duration (sec)**	**Input 3: Swell Duration (sec)**	**Input 4: Transient Duration (sec)**	**Input 5: Absolute Minimum voltage (p.u.)**
1.	L Low	ESH Extremely short	ESH Extremely short	ESH Extremely short	VL Very Low
2.	M Medium	VSH Very Short	VSH Very Short	SH Short	L Low
3.	H High	SH Short	SH Short	SH Short	M Medium
4.	VH Very High	M Medium	M Medium	-	H High
5.	EH Extremely High	-	-	-	-

TABLE 2: FUZZY SETS DEFINED FOR THE OUTPUT VARIABLES

Membership function	**Output 1**	**Output 2**	**Output 3**
1	I sag Instantaneous sag	I swell Instantaneous swell	I interrupt Instantaneous interruption
2	N sag Non sag	N swell Non swell	N interrupt Non interruption
3	M sag Momentary sag	M swell Momentary swell	M interrupt Momentary interruption

The membership functions defined for the five input variables are as shown in fig. 3 to 7. The output variables are defined by three membership functions as shown in fig. 8 to 10.

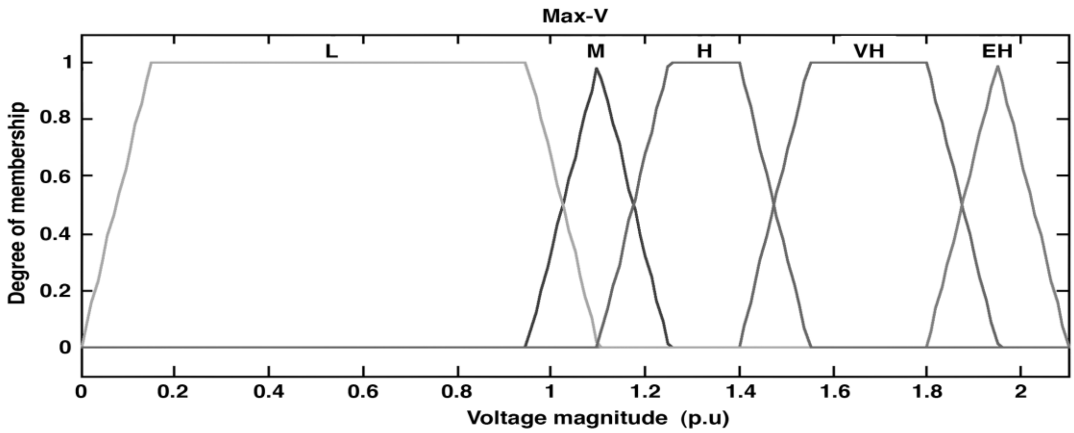

Fig. 3 Maximum voltage input membership function

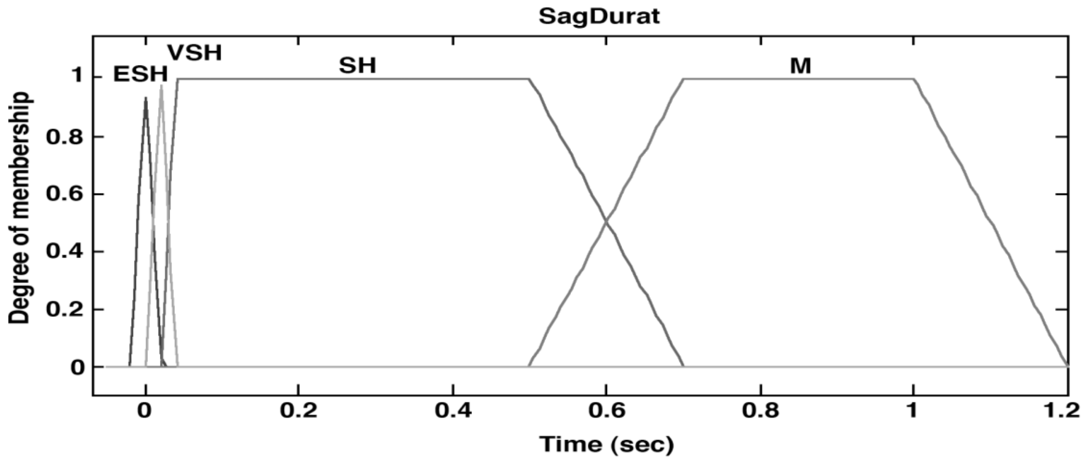

Fig. 4 Sag duration input membership function

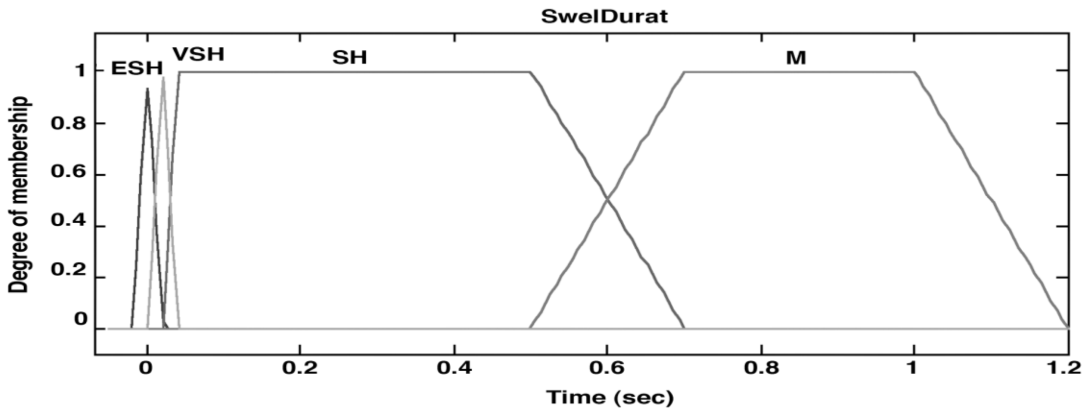

Fig. 5 Swell duration input membership functions

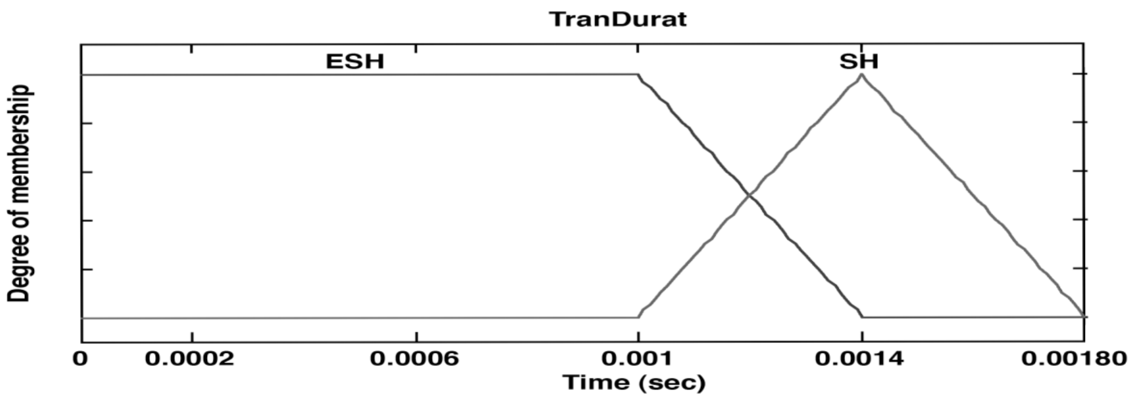

Fig. 6 Transient duration input membership functions

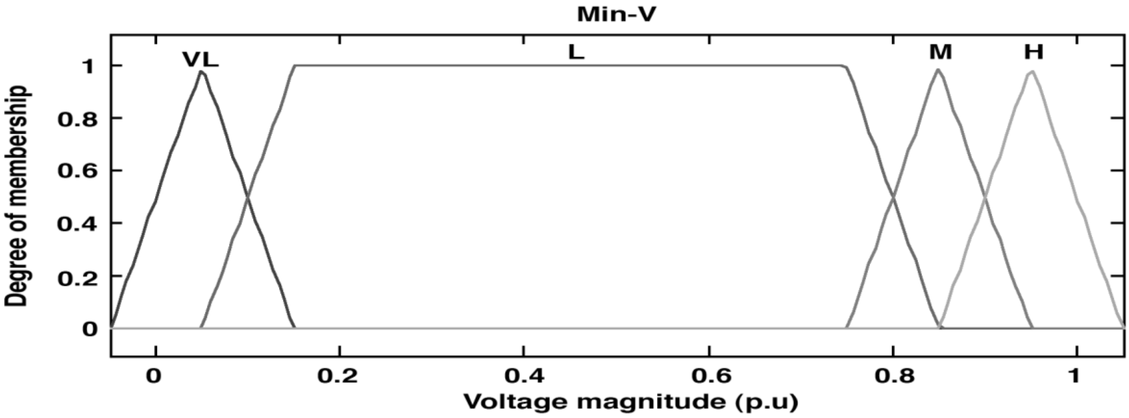

Fig. 7 Absolute minimum voltage input membership function

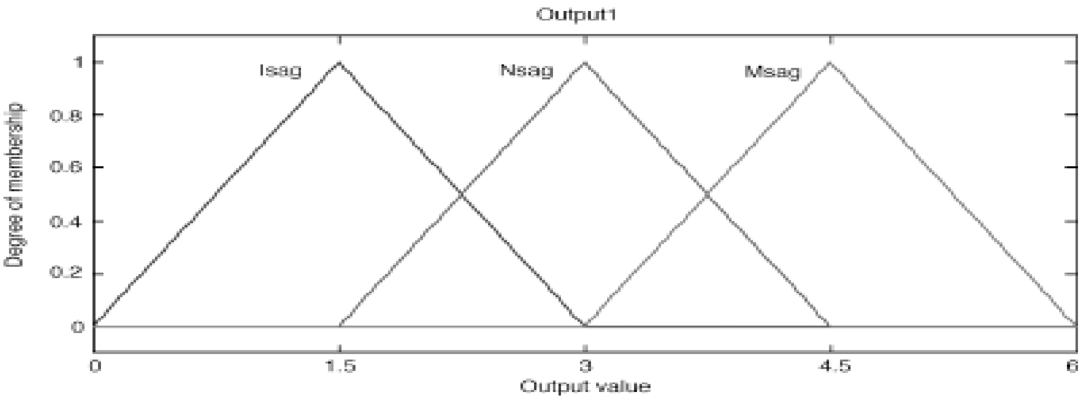

Fig. 8 Output1 membership function

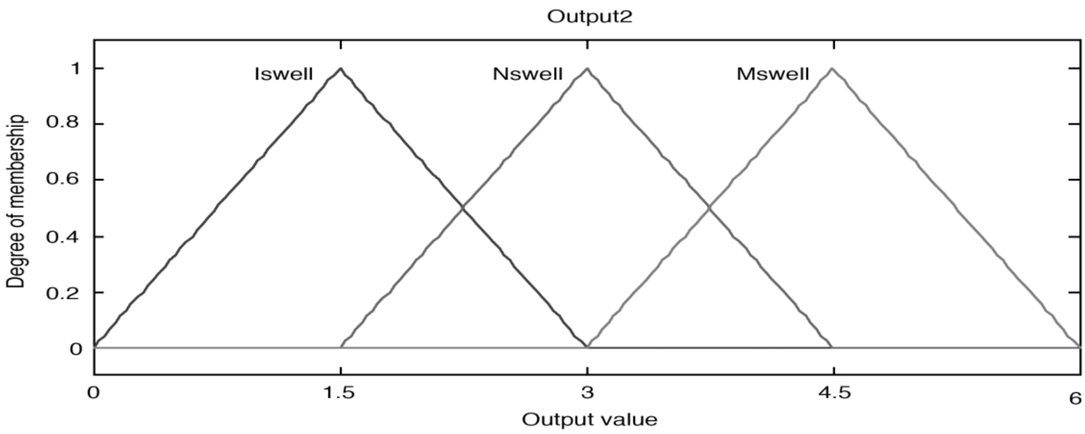

Fig. 9 Output2 membership function

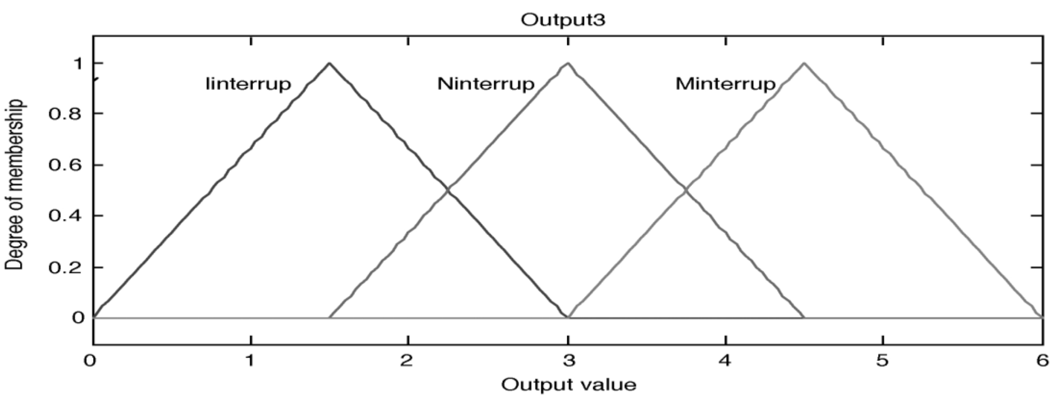

Fig. 10 Output3 membership function

If-Then rules (30) have been generated for classifying sag, swell and interruption disturbances. These rules are represented in the following form:
IF premise THEN consequent
Example of the generated rules for identifying sag, swell and interruption and classifying them to instantaneous, momentary and non sag, swell and interruption are given as follows:
(1) If (Max-V is L) and (Sag Durat is SH) and (Swell Durat is ESH) and (Tran Durat is ESH) and (Min-V is L) then (Output1 is I sag) (Output2 is N swell) (Output3 is N interrupt). etc.
To illustrate the classification results of the proposed fuzzy-expert system, 30 case examples were considered and analyzed.

5. CONCLUSION

Identification and classification of voltage and current disturbances in power systems is an important function in power system monitoring and protection. A Fuzzy expert system has been developed to increase the accuracy of compensation system as well as detecting and classifying short duration voltage disturbances, namely, instantaneous, momentary and non-sag, swell and interruption from the 8, 32 and 128 cycles waveforms. For the fuzzy inference system, fuzzy If-Then rules has been created based on five fuzzy inputs and three fuzzy outputs. Prior to the fuzzy implementation, a simple signal processing technique based on FFT and rms averaging technique have been used to derive the features of several disturbances. The proposed fuzzy-expert system has been tested with various types of real voltage disturbances so as to verify its accuracy in classifying sag, swell and interruption. The test results reveal that the proposed system has accurately identified and classified 98.4% of the tested voltage disturbances.

6. REFERENCES

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