CHAPTER 10

Conclusion and Suggestion for Further Research

10.1 Conclusion
10.2 Further Research

"Not only in research, but also in the everyday world of politics and economics, we would all be better off, if more people realized that simple non-linear systems do not necessarily process simple dynamical properties.

Robert May
Chapter 10.

Conclusion and Suggestion for Further Research

10.1 Conclusion

The conventional relays are used as a sensor to sense the fault in the power system. Relays sense the faults and send the command signals to the actuating mechanism of circuit breakers so as to interrupt the faulty section of power system in order to protect the costly power system equipment as human operators. The conventional relays are set to respond only a crisp value, but the values closer to the set crisp values are also as dangerous as the set value, to which the conventional relay will not respond. The repeated application of such a high values of voltage or current around the set value also causes a severe damage in the power system. To incorporate the fault values closer to or around set value of conventional relay, needs to develop such a system which may respond the fuzzy set values. Hence fuzzy sensor design is proposed here to eliminate the drawbacks of conventional relay.

Fuzzy logic is a very strong theory and soft computing tools used for building expert and intelligent systems where uncertainty is involved. Using this theory human reasoning can be modeled. Fuzzy logic along with Artificial Neural Network and Genetic Algorithm are used here to design fuzzy relay sensor to overcome the problem of conventional relay. One can combined the rule base of different relay like: IDMT relay, Differential relay, Distance relay, and Directional relay to develop a single rule base which incorporates characteristics of all the above types of relays for use in power system protection, instead of different physical relays. This is one of the most important benefit of fuzzy relay sensor.

Any fuzzy sensor is essentially consist of a controlling and reasoning unit called inference engine. This inference engine actually provides intelligent behavior as human being, to fuzzy relay system. The inference engine is basically rule base system, which has a number of IF – THEN rules derived from the antecedent and consequent variables designed previously. These parameters are characterized by many fuzzy predicates in the form of fuzzy sets. The IF – THEN rules are formed as follows -

IF antecedent is P THEN consequent is N
Where P and N denotes positive and negative fuzzy sets respectively. To obtain the crisp output or sensor output signal or command signal become essential, that is carried out by defuzzification methods. The individual application of Neural Network and Genetic Algorithm are also discussed. MATLAB software is used for simulation of characteristics curve of different relay. Fuzzy relay or fuzzy relay sensor is basically an expert system which performs an expert and specific job during the fault clearance in the power system by sensing the abnormal fault signal and sending the actuating signal to the actuating mechanism off circuit breakers in order to take corrective measures to clear the fault.

There are different types of relay as discussed in section 3.8 of chapter 3, but inverse definite time relay (IDMT), differential relays and distance relays are considered in this research work for development of fuzzy relay sensor. In chapter 4 and 5 the characteristics curve of IDMT relay is discussed and fuzzified and rule base is developed, result shows that the behavior of fuzzy relay sensor is very much closer to the conventional relay sensor. Simulated results after training the neural network, designed for learning the antecedent and consequent variables and its corresponding membership functions are tabulated in Table 4.2 and 4.3. Error obtained are in acceptable range.

In chapter 5 rules in rule base are increased by taking some more fuzzy predicate. From the simulated curve it is clear that by increasing number of rules we are getting smooth curve (See Fig. 5.7) as compare to the simulated curve shown in Fig. 4.12.

In chapter 6 and 7 study of behavior of IDMT relay is continued. This time, time relationship formulae between plug setting current and operating current (Equation 6.1) is considered for fuzzification. After fuzzification rule base is developed and simulated characteristics curve is drawn (See Fig. 6.7) this curve is very similar to conventional IDMT relay curve. Sensitivity of fuzzy relay sensor is also checked with three parameters error \( e \) and change in error \( \Delta e \) as input and change in operating time \( \Delta t \) as output. The result is found satisfactory. It is seen that the sensitivity and operability of fuzzy relay sensor is good and quick respectively. Fig. 4.5 and 5.1 and equation 6.1 shows the inverse behavior of IDMT relay with operating time. This characteristics is desirable for the device used as a protective device in power system [81]. The over current and earth fault relay used in power system protection have similar inverse characteristics. The higher the amplitude of the plug setting current level, lower would be the operating time. It means for a high amplitude or hazardous current the relay must respond fast and for lower amplitude current the relay should operate slow or it should not interrupt the supply of electrical energy unnecessarily. One can see from the Fig. 4.12, 5.7 and 6.7 that the proposed relay displayed the required behavior and hence the fuzzy relay is acceptable for power system protection as it may reason where and when is to be operate and where and when is not to be operate like a human being. Training of neural network [3,47,79,95,98] using
parameter designed by fuzzy set theory [28,52,106] provides us a concrete method of determination of membership function and approximating the consequent variables to obtain the inverse characteristics.

The hybrid application of Fuzzy – Neuro, Neuro – Genetic algorithm for approximation and optimization of results are also carried out in chapter 7. Hybrid systems using Neural Network and a soft computing tool Genetic Algorithm is discussed. Different Neuro – Genetic models are proposed and simulated result is found satisfactory with permissible range of error.

A new type of relay known as differential relay with entirely different principle is discussed in chapter 8. Fuzzy rule base has been developed after fuzzifying the characteristics curve of differential relay. Simulated curve (Fig. 8.10) is presented and its behavior is found satisfactory. A digital based H/W circuit for fuzzy comparator based differential relay is proposed, which is simulated for antecedent variable and consequent variables of fuzzy relay, result is presented in Table 8.1. Fuzzy comparator based differential relay is designed and tested for its performance in the simulated model.

The application of fuzzy relay designed previously was also used in protective scheme called relaying scheme. Behavior of protective relaying based on distance and direction are discussed in chapter 9 and a fuzzy relaying using Local Area Network (LAN) is proposed (Fig. 9.4). Three parameters distance, direction and amplitude are fuzzified to develop rule base for fuzzy server sensor. This rule base is containing 36 rules. The performance of fuzzy relaying is tested and was found satisfactory. LAN for small generating station or sub station was proposed and protective model was developed using MIMO (Multi Input Multi Output) Neural Network. The outcome of this research work provides blue print and are helpful to develop an expert system for power system protection.

10.2 Scope for Further Research

The further research in this field is also expected, and following suggestions are being extended in this regards.

1. A large module based protective system may be developed consisting of all the aspects of power system protection in modular basis.
2. Power system is a very complicated network, and load monitoring in different points are essentially required. This may be carried out by developing a fuzzy base load monitor using fuzzy – chaotic methods.
3. It still requires to develop an effective relaying scheme on graded section basis using Fuzzy logic, Neural Network and Genetic Algorithm theories.
4. The more number of rules in the rule base of fuzzy relay could enhance the performance of fuzzy relay. Its performance evaluation in either prototype testing lab or actual power system is required.

5. There are various types of relays in addition to the relay discussed in this research work, they may also be considered for developing fuzzy sensor.

6. A fuzzy expert system incorporating the characteristics of all the relays used in power protection system may be developed in forthcoming research.

7. Physical implementation of fuzzy sensor as an expert system may be a major project, which can be taken in hand and can be accomplished using embedded programming.