Advance Guess of Electricity Price by AI with FIS

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ABSTRACT : DEREGULATION HAS MAJOR IMPACT ON ELECTRICAL POWER SCENARIO IN CURRENT ERA. PRICE GUESSING IS NECESSARY TO DEVELOP BIDDING STRATEGIES TO MAXIMIZE THEIR BENEFITS AND UTILITIES, ESPECIALLY FOR SPOT MARKETS AND SHORT-TERM CONTRACTS. THE CURRENT ELECTRICITY MARKET DEREGULATION IS EFFECTIVELY LOOK AFTER BY PRICE ESTIMATION TOOL. POWER SYSTEM RISK ASSESSMENT AND OTHER DECISION MAKING TOGETHER WITH PLANNING AND OPERATION, ARE WELL EXECUTED BY PRICE ESTIMATION. IN THIS WORK, FUZZY INFERENCE SYSTEM (FIS)IS USED TO GUESSS HOURLY, SHORT PERIOD ELECTRICITY PRICE. THE ELECTRICITY DATA FROM THE INDIAN ENERGY EXCHANGE WEB SITE, HOURLY PAST LOAD AND HOURLY PAST PRICE DATA, IS UTILIZED TO DEVELOP THE SYSTEM. PRICE PREDICTING ACCURACY EVALUATED BY THE CALCULATION OF MEAN ABSOLUTE PERCENTAGE ERROR (MAPE). THE RESULT INDICATES THAT AI SPECIALLY FIS METHOD, PRICE PREDICTION ACCURACY IS CONSIDERABLY BETTER.

INDEXTERMS – FUZZY INFERENCE SYSTEM (FIS), ELECTRICITY PRICE GUESSING, MEAN ABSOLUTE PERCENTAGE ERROR (MAPE), PRICE OF ELECTRICITY (POE)

1. INTRODUCTION

From every activity of electricity market, electricity price has been given first choice by launching restructuring in the electric power scenario. Across universe, due to deregulation, most of the electricity market, future demand and PoE, electricity producer and electricity traders for making bidding strategies, as well as system operators for smooth take up of the market, PoE and future demand become important for market players. Based on its requirement, price guessing can be classified into short- period (few days), middle period (few months) and longer-period (few years)

Various models have been used in Power systems for achieving guessing accuracy. They are: regression, statistical and state space methods. Artificial Intelligence (AI)based methods have been searched based on expert systems, artificial neural networks, fuzzy systems, evolutionary programming and various combinations of all above.

Neural networks are a effective, efficient and flexible user-friendly tool for guessing, provided that enough data for training, necessary selection of the input–output samples, appropriate number of hidden units and sufficient computational resources available. NN have the well-known benefit of dealing successfully with numerous nonlinear functions and rectify difficulties of any type of date which has no relationship or not solved it out quickly for any input-output, because NN are run by data.

2. Electricity Price Prediction

Market-clearing price (MCP) is the basic pricing idea and PoE is the peak factor for all market participants in the power market. MCP is the only price of whole system where there is no congestion of transmission. Zonal market clearing price (ZMCP) or locational marginal price (LMP) can be employed for the solution of congestion.

Basic reason for electricity price variation is that the supply and demand should be synchronised on a second-by-second basis. Other reasons follow:

Up and down in fuel price
Fluctuating Load
Changes in electricity production
Uncertain Generation (outages)
Congestion in transmission
Look out variation in market player
Adjustment in Market

3. Performance Evaluation of Price Prediction

Determine the accuracy of the proposed approaches in guessing electricity prices, forecasting error is considered as the most important parameter. This accuracy is calculated in function of actual market prices that prevailed. Criterion of mean absolute percentage error - MAPE, is the standard parameter for evaluation of the predicting accuracy.

The MAPE criterion is given by:

$$\text{MAPE} = \frac{100}{N}\sum_{h=1}^{N}\frac{|\hat{p}_h - p_h|}{\bar{p}}$$

And

$$\bar{p} = \frac{1}{N}\sum_{h=1}^{N} p_h$$

Where,
$\hat{p}_h$ and p_h are respectively the predicted and actual electricity prices at hour h,
$\bar{p}$ is the average price of the predicting interval and
N is the number of predicted hours.
PoE can at particular hours go up to tens or even higher times of its usual value. It goes down to zero or even to negative at other interval of times. Therefore, average price taken in formula to avoid the problem caused by prices near to zero.

4. Fuzzy Logic.

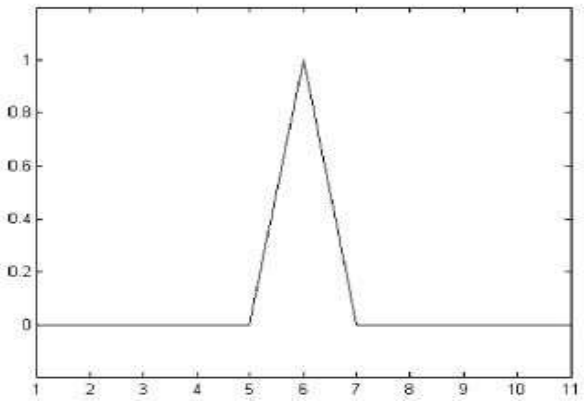
Flexible. - It is layer on more functionality without starting again from scratch for the given system.
Based on natural language. - FIS is built on the structures of qualitative description used in everyday language which make same basis for human communication.
Built on top of the experience of experts. - Fuzzy logic lets you rely on consider the experience of people who understand the system in contrast to NN, which deals with training data and generate impenetrable models.
Model of nonlinear functions of random complexity. -By using adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS) for any set of input-output data, fuzzy inference system can model randomly.
Blended with conventional control techniques. - It does not replace conventional control methods augment them and simplify their implementation.
Tolerant of imprecise data. - Fuzzy reasoning builds imprecise things for careful inspection into the process rather than tacking it onto the end.

Fuzzy Sets

It is a generalization of ordinary set, which allows the degree of membership for each element to range over the unit interval [0, 1]. Therefore, MF of a fuzzy set maps each element of the universe of discourse to its range space, which, in most cases, is assumed to be the unit interval.

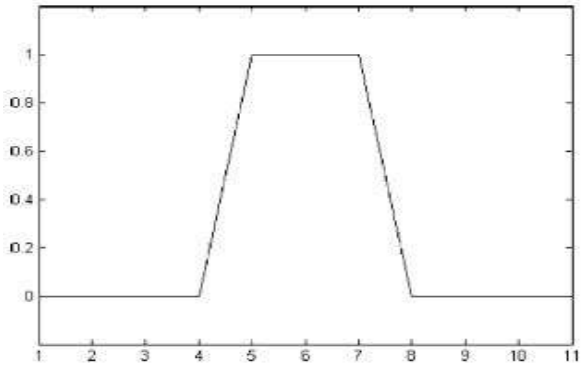
Membership Functions

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is referred as universe of discourse. (UOD)
MF must satisfy one condition that it must vary between 0 and 1.
A fuzzy set is an extension of a classical set. If X is the UOD and its elements are denoted by x, then a fuzzy set A in X is defined as a set of ordered pairs.
$A = \{x, \mu A(x) \mid x \in X\}$
$\mu A(x)$ is called the membership function (or MF) of x in A.
The membership function maps each element of X to a membership value between 0 and 1.
Fig shows a triangular membership function of a fuzzy set $\Lambda(x; \alpha, \beta, \gamma)$.



$$\Lambda(x;\alpha,\beta,\gamma) = \begin{cases} 0, & x < \alpha \\ \frac{x-\alpha}{\beta-\alpha}, & \alpha \le x \le \beta \\ \frac{\gamma-x}{\gamma-\beta}, & \beta \le x \le \gamma \\ 0, & x > \gamma \end{cases}$$

Fig 1 Triangular Function



$$\pi(x;\alpha,\beta,\gamma) = \begin{cases} 0, & x < \alpha \\ \frac{x-\alpha}{\beta-\alpha}, & \alpha \le x < \beta \\ 1, & \beta \le x \le \gamma \\ \frac{\delta-x}{\delta-\gamma}, & \gamma < x \le \delta \\ 0, & x > \delta \end{cases}$$

Fig 2 Trapezoidal Function

Logical Operations

The min operation by using the function min (A, B) indicate the statement A AND B, whereas the max operation by using the function max (A, B) indicate the statement A OR B. The operation NOT A becomes equivalent to the operation 1-A. The input values can be real numbers between 0 and 1.

If-Then Rules

These if-then rule statements are utilized for making the conditional statements that comprise fuzzy logic.

A single fuzzy if-then rule assumes the form, - 'if x is A then y is B'.

where A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion. For example – 'If service is good then tip is average'. Making inference from if-then rules is a three-part process.

i) Fuzzify inputs: By way of antecedent, every statement of fuzzy are sort out to remain between 0 and 1 its degree of membership. ii) Apply fuzzy operator to multiple part antecedents: Sequence of antecedents are work out by fuzzy logic operators and sort out antecedent to remain between 0 and 1. iii) Apply implication method: Fuzzy set output is done by using degree of support of whole rule. According to this, fuzzy set output is truncated when antecedent is semi correct.

Fuzzy Logic GUI tools for FIS :

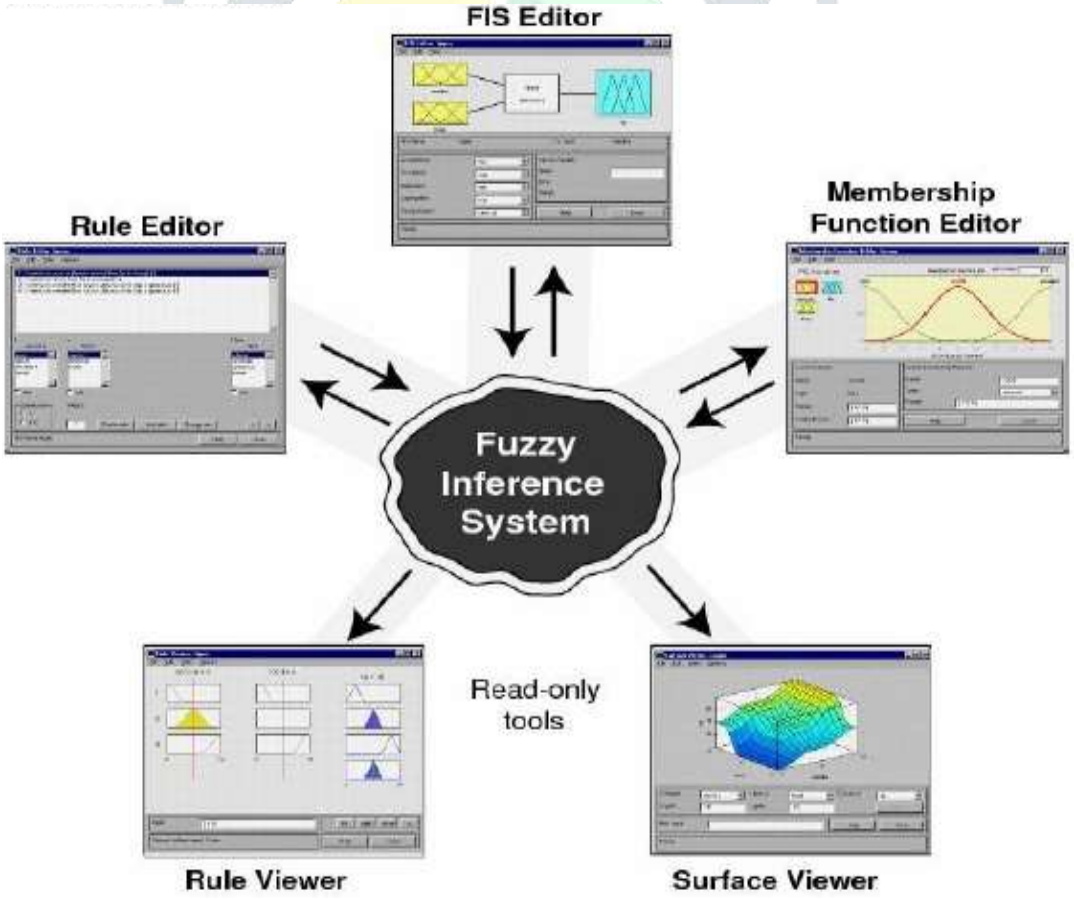


Fig. 3 Fuzzy Logic GUI toolbox

Design of Fuzzy System

Modulus to be follow for developing FIS are:

1. Normalization: It transforms scale of physical values with identification into normalized UOD.
2. Fuzzification: Using the linguistic variable of the rule-antecedent, it calculates its degree of membership, for a crisp input, when institution regards to individual rule firing. Otherwise, it replaces a crisp input into fuzzy for composition-based institution.
3. Inferencing: By combing the fuzzy rules, skill person controls the policy for good governance of system operation.
4. Defuzzification: Transform updated fuzzy set output into a single (0,1) value.
5. Denormalization: Execute a scale alternation of the (0,1) output value, which shows (0,1) value onto its physical domain. Fuzzification:

Here, the crisp (0,1) values are changed as per appropriate fuzzy set, into degrees of membership. A MF allow only (0,1) value as argument and revert the degree to the value belongs to fuzzy. Here, 0 means completely outside the fuzzy set, and 1 means completely within the fuzzy set, or in between any value.

Fuzzy Inference System (FIS)

It's a nonlinear way to express input to output space. And rules are connection between above express space.

Suppose x is the input linguistic variable with a membership function A, and y is the output linguistic variable with a membership function B. Then, structure of the rule is, IF x is A THEN y is B.

In the above rule, the portion after the IF and before the THEN ('x is A') is called the premise or antecedent of the rule. And the portion after the THEN ('y is B') is called the conclusion or consequent of the rule.

Defuzzification

Inverse of the fuzzification step is called Defuzzification. Defuzzification step revert the intuition values into (0,1) values. It deals the activity to get final output as variable values So, it includes sketch a one or many output value(s) from conclusive fuzzy set passed on inference stage.

CENTROID or MAXIMUM invariably common methods. In CENTROID, (0,1) value of the output variable is found out and variable value of the CoG of the MF is found for this.

Day Ahead Price Prediction by Fuzzy Logic

The proposed algorithm for day ahead price Prediction consists of four stages.

1. Rule base Design
2. Calculate point predicted value
3. Testing of rule base records
4. Rule base checking and modification
5. Error interpretation.

Rule Base Design

Firstly, develop rules for fuzzy model, then this will relate fuzzy input with required output. Here, the previous price and previous load taken as inputs and they are used for predicting single output as predicted price.

Below Table shows the rules got after we list all the fuzzy parameters for hourly price.

Previous Load (pre load)	Previous Price (pre price)	Forecasted Price (predicted price)
low	Lower	Lower
low	moderate	Lower
low	Higher	Lower
medium	Lower	Lower
medium	moderate	Moderate
medium	Higher	Moderate
high	Lower	Lower
High	Moderate	Moderate
high	Higher	Higher

Table 1: Rules for Fuzzy Price Forecasting

Above table rule base interpret as follows:

If Previous Load is low AND Previous Price is lower Than Forecasted Price is lower. If Previous Load is medium AND Previous Price is moderate Then Forecasted Price is moderate.

If Previous Load is high AND Previous Price is higher Than Forecasted Price is higher.

Calculate point predicted value

A FIS perform nonlinear function from input to output space. Mamdani FIS is used here. Defuzzification done for finding point estimate of prediction by fuzzy logic. CoA process generates prediction thoroughly to all rules numerically.

Centroid of area ZCOA =

Where μA(z) aggregated output MF.

Testing of rule base records

Testing is done using historical data for getting rule base. Iterative process for getting satisfaction is done by changing shape of fuzzy MF and new rule base is achieved. The iterative process is continue till rule base give minimum error. Here, day ahead price prediction by FL is tested using trapezoidal MF and triangular MF for the same rule base.

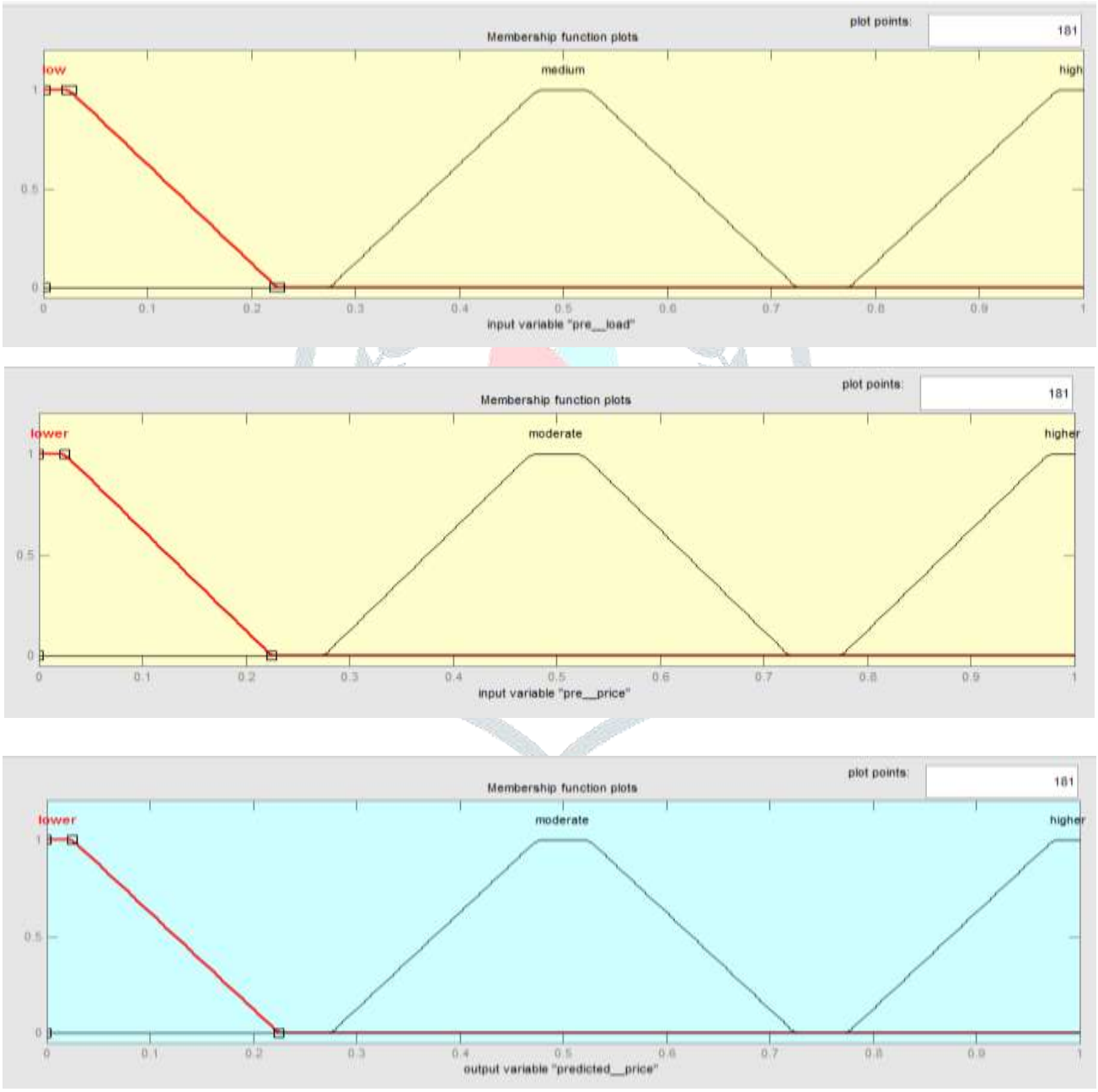


Fig. 4.Trapezoidal Membership Function Plots of i/p & o/p variables

Rule Base checking and modification

New rule observation does not conflict with previous rules, then, it can be added promptly to existence fuzzy rule base. Only update fuzzy rule whenever system in real time gives new values and operational.

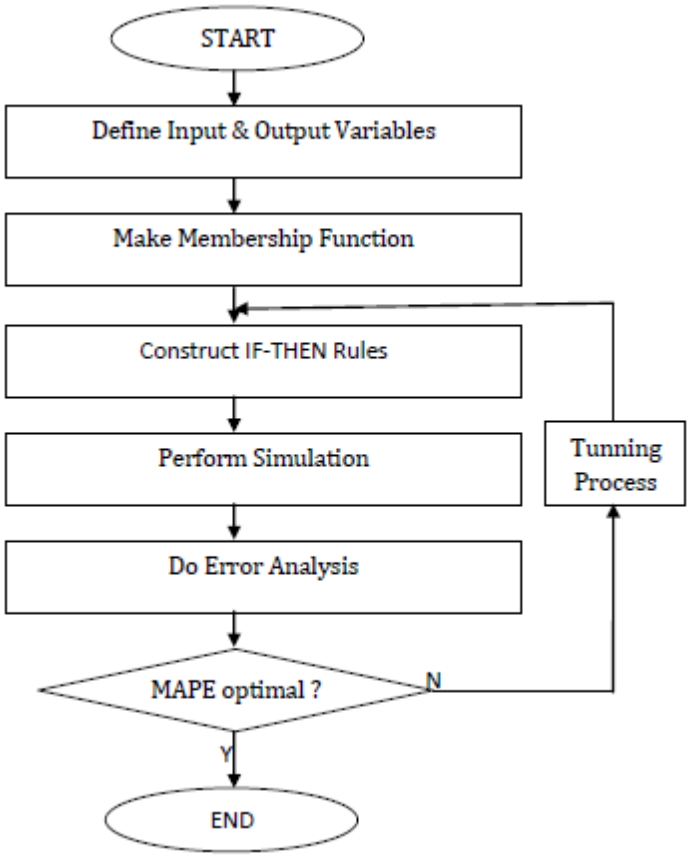


Fig 5 Flowchart of fuzzy logic model

5 Results

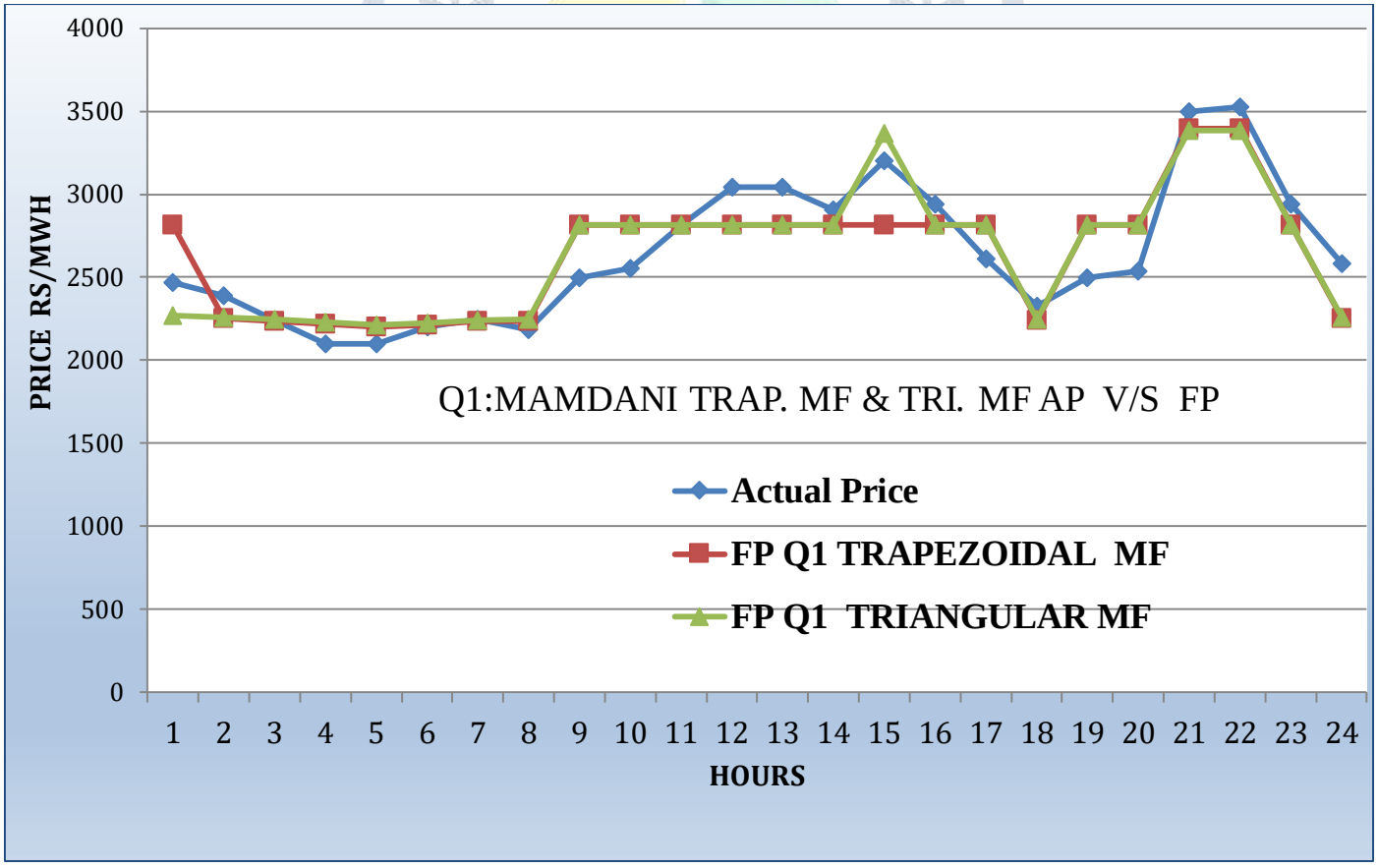


Chart Q1 : FUZZY MAMDANI Trap. & Tri MF Network's, AP V/S FP

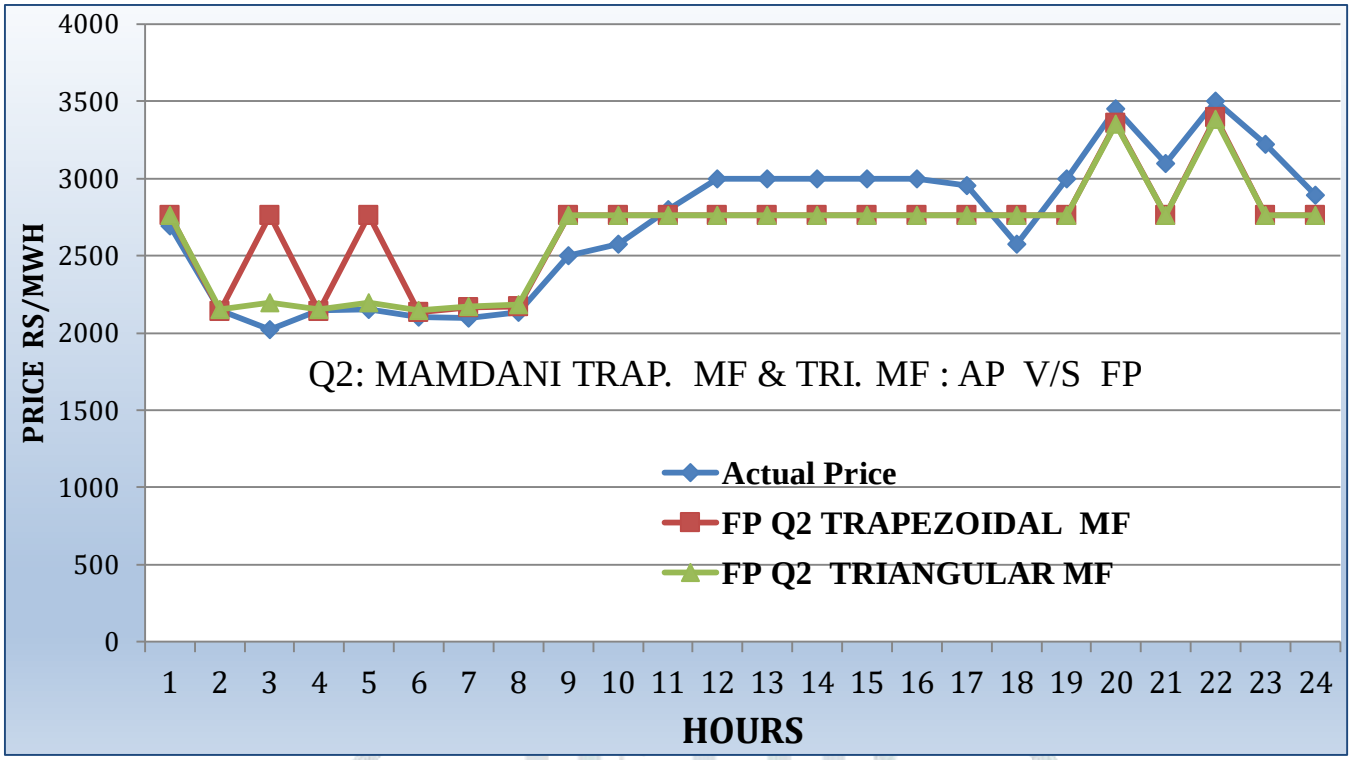


Chart Q2 : FUZZY MAMDANI Trap. & Tri MF Network's, AP V/S FP

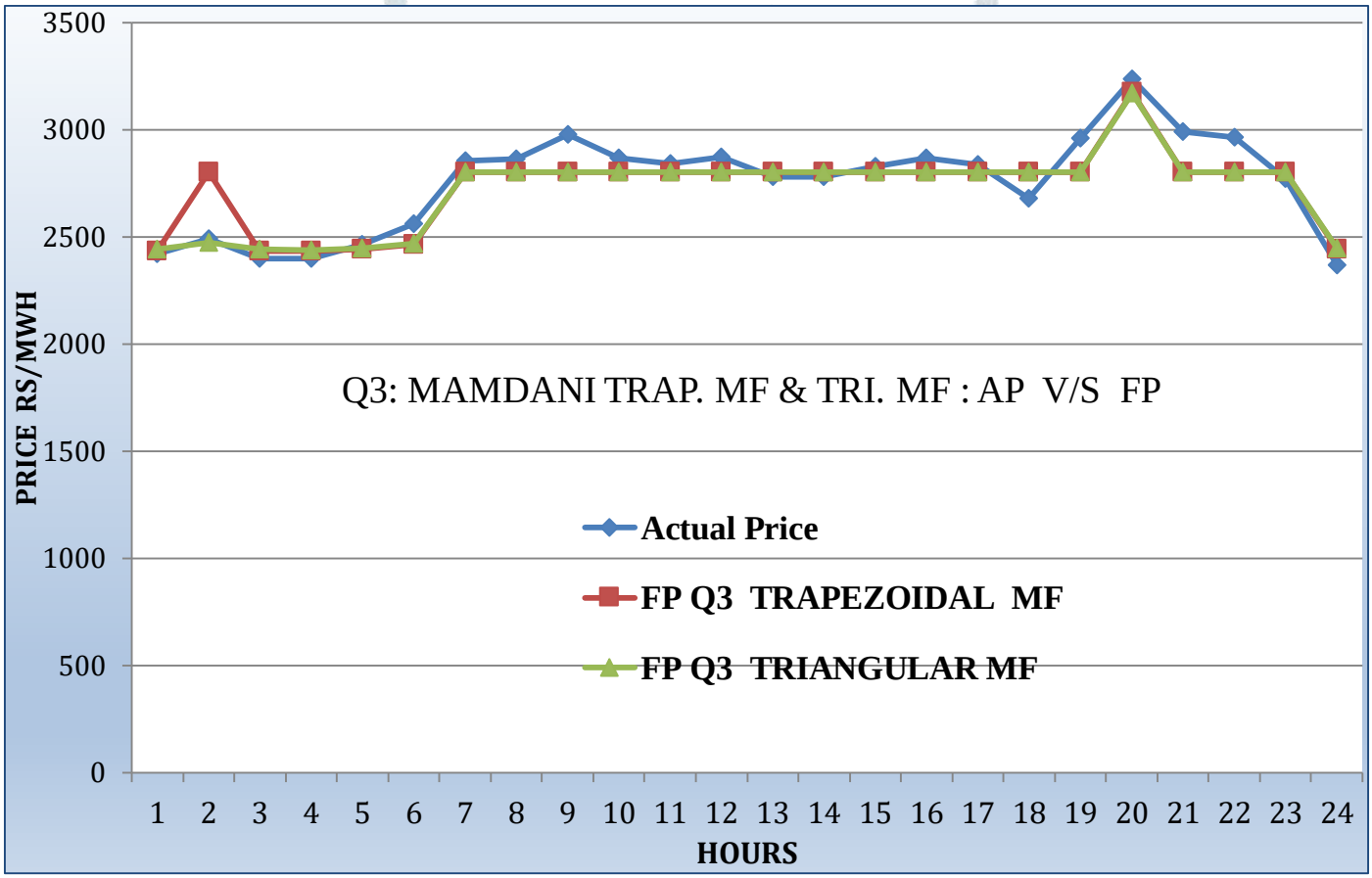


Chart Q3 : FUZZY MAMDANI Trap. & Tri MF Network's, AP V/S FP

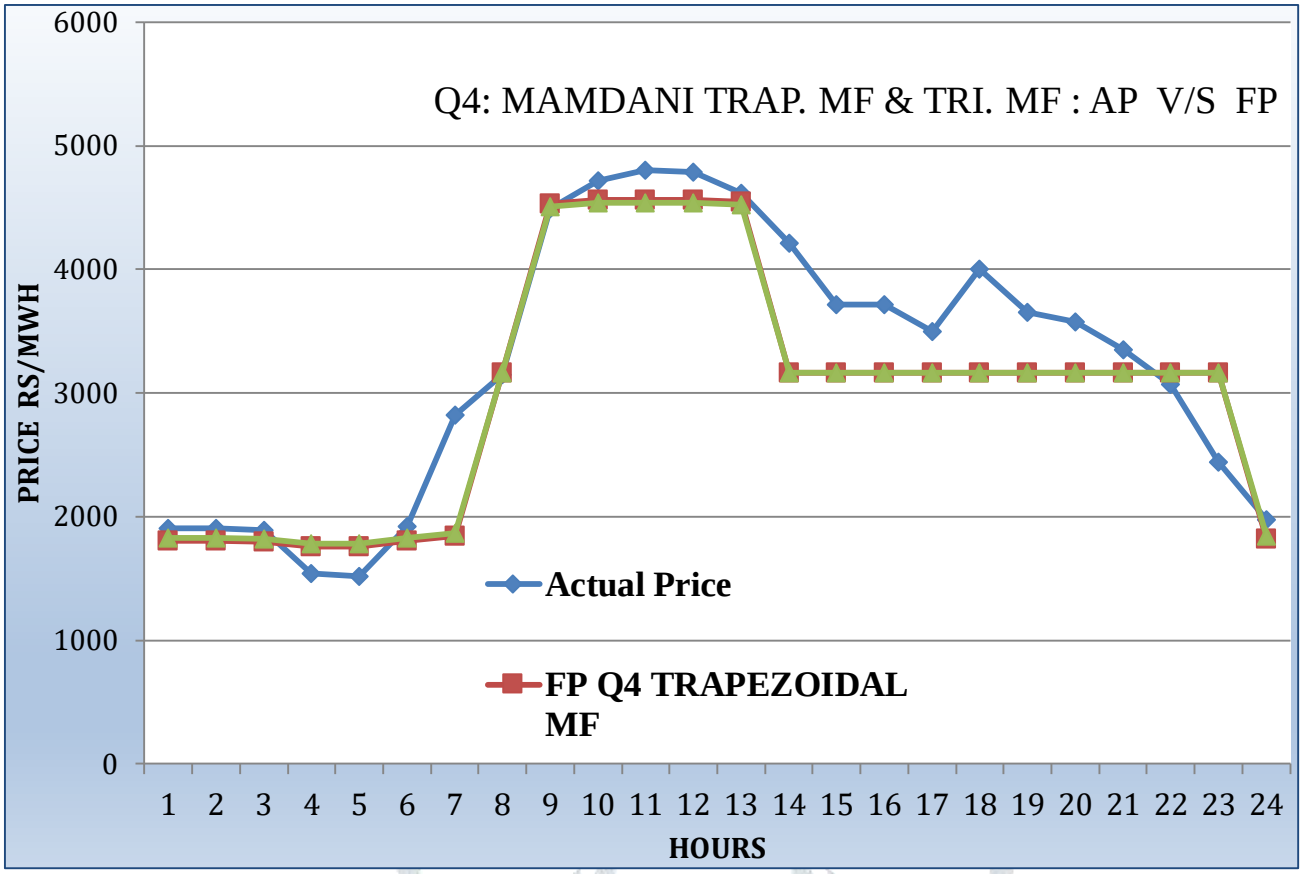


Chart Q4 : FUZZY MAMDANI Trap. & Tri MF Network's, AP V/S FP

Table- MAPE value of different FIS's Membership Function N/W'S

	Value of MAPE	
	Mamdani Trapezoidal MF N/W's	**Mamdani Triangular MF N/W's**
Q 1	**0.0543**	**0.2549**
Q 2	**0.6725**	**1.4596**
Q 3	**0.9273**	**1.2485**
Q 4	**2.6425**	**4.1564**

6. Conclusion:

Electricity price in short interval of time, due to its high volatility, making it difficult to guess its future value. FIS proposed approaches, significant results in the predicting performance has been observed. Selection of input data and careful processing is the prime factor in the procedure. The past price and demand data, selected as input factor for PoE guessing.

1 Inference from the result table clearly indicate that Mamdani FIS using trapezoidal membership function achieved MAPE value lesser than Mamdani FIS using triangular membership function.

2 From different quarter charts, it is clear that guessing electricity price is nearer to actual price, during the load requirement is low specially late morning to early morning i.e. 11.00pm to 7.00am . More fluctuations in price Prediction can be seen in rest of the day hours, which justify that load demand is the most significant effective factor in electricity price guessing .

7 Future Scope :

Future scope of work could be,

1 Inculcate other PoE affecting major factors which may lead to result of precise electricity price guessing.

2 Hybrid model FIS-ANN could be evaluated with Mamdani Trap. MF and ANN model, for more efficient performance of electricity price guessing.

accuracy.

3 Using ANFIS, Genetic algorithm or combination methods could be more efficient short interval electricity price guessing .

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