

# Optimization of perturb and observe based fuzzy logic MPPT controller for independent PV solar system

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*Abstract:* - In this paper, a novel intelligent Fuzzy Logic Controller (FLC) based on Maximum Power Extracting (MPE) of photovoltaic standalone system is proposed, which can handle the uncertainties of the rules under high deviations in climate conditions. Traditional Perturbation and Observation (P&O), hill-climbing MPE structures are examined. The MPE used a boost converter controller. The novel MPPT controller develops enhanced P&O based on possible power extractor search technique by fuzzifying rules of such method and eliminates the conventional drawback. A new FLC based improved P&O offers a precise and quick convergence to MPE during changing climatic and steady-state conditions compared to existing P&O and hill climbing method. The development of the suggested MPE is confirmed in simulation MATLAB at dissimilar operating circumstances.

*Key-Words:* - Power Systems, Applications of Fuzzy Logic, Peak power point tracking, Enhanced perturb and observe technique, Fuzzy logic controller based MPPT, solar photo voltaic system, DC to DC converter

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## 1 Introduction

The Direct Current to Direct Current (DC) converter uses variations of the output voltage according to its duty cycle. The buck-boost and buck converter lose half of their input power due to input current series switching. For that the boost converters must be excluded from extreme tracking applications [1]-[8]. The boost direct current to direct current converter has continuous input current, but the yield voltage is constantly larger than the primary side which may not attain maximum power transfer function in few cases, maximum power voltage is less than input[2]-[3]. The MPPT approach traces the possible higher power via decreasing or increasing current and voltage [4][5]. Henceforth, the utilization of step up is successful as it decreases or increases current at voltage's expense and it's additionally ready to exploit all the surviving power from photovoltaic due to its nonstop of input current source [6][7]. Maximum power extracting algorithm represents the best load for the PV panel, generating appropriate voltage for the load [8][9]. The PV modules yield exponential function curves for current and voltage, where the maximum power ascends at the curve's joint knee [10][11]. The solar PV power and voltage

characteristics are nonlinear and influenced by the temperature and irradiance differences [11][12]. The power tracking uses a controller and reasoning to search for the knee, which, thus, enables the dc to dc step up converter to excerpt the extreme power from the photovoltaic panel [13]. The tracing technique offers a new reference signal for the control and excerpts the extreme power from the photovoltaic panel [14]. Literature has recommended many MPPT methods. The Incremental-Conductive (INC) technique is calculated on the derived function of power over voltage or current being zero at the MPP, negative on the privilege or right hand side of the possible point power and positive on the left of the maximum point [15]-[23]. This technique requires complex calculation to give good performance under quick weather situations change. Besides, the following peak power time is comparatively long for minor step size [16][17]. Hill-climbing technique works by perturbation of the PV structure which variations the power electronics converter duty cycle and detects it on the output power, and then determining the different way of the duty-cycle to excerpt extreme power [18][19]. The hill-climbing technique has slow reaction, particularly under changing weather circumstances because the MPPT approach gives the choice directly for the duty cycle by announcing a controller of error

signal. The current /voltage-based MPE approximates the proportion between the greatest maximum power current/voltage and the short circuit current/open circuit voltage under dissimilar weather circumstances [20][21]. P&O conventional approach is usually applied due to its simplicity, low cost and easier [14][15]. Perturb and observe works efficiently under changing weather circumstances where it can reach the error signal due to its parting between the MPE technique that controls the reference point and the duty-cycle ensuing from varying the reference signal[22][23]. Hence, P&O approach employs the MPE for the reference indication, while the direct current to direct current converter can be controlled independently. Among dissimilar artificial intelligent controllers, FLC is the simplest to integrate with the structure. Lately, FLC has received an increasing attention from researchers for motor drives, converter control, and other process control as it offers better reactions than other traditional controllers [8]-[13]. The inaccuracy of the climate fluctuations that can be exposed by photovoltaic arrays can be exposed accurately employing FLC based controller. In order to achieve the merits of the FLC algorithm, the greater energy tracking calculation is integrated utilizing fuzzy based controller so that the complete control structure can constantly deliver maximum power transfer from photovoltaic panel to the converter side, in spite of the unpredictable climate circumstances. The problem of most of the FLC-based MPE algorithms [14]-[18] is that the tracing point is situated away from the MPE when the weather situations variation. Moreover, the MPE tracking control contingent upon duty-cycle variations causes negligence in power converter error signal controller. Though, it is crucial to control the duty cycle of the charge converter and to trace the MPE depending on the reference signal, not duty cycle [19-20].

This article demonstrates a novel FLC based Modified Perturb and Observe (MPO) technique for MPE standalone PV scheme. The designed MPE tracking is able to exploit the merits of the conventional P&O process and eradicates its problems. The MPE is analyzed by converting the improved P&O algorithm into 37 fuzzy rules after the controller dual inputs and single output have been divided to seven fuzzy subsets. As the designed technique always transfers extreme power from photovoltaic arrays.

## 2 Improved Perturbation and Observation approach

The orthodox P&O algorithm is working on the subsequent principle: if the voltage or current of the PV array is perturbed in a particular direction and the PV power rises, this implies that the functioning point has traced toward the peak point power and, hence, the functioning voltage or current would be perturbed in the same path. Else, if the power reduces, the functioning point has progressed away from the peak point power and, so, the route of the functioning voltage or current perturbation must be inverted.

P&O functions by varying the power electronics converter voltage reference signal or duty-cycle and detecting its influence on the output power. The perturbation and observation are the best usually used system as ease of execution, simplicity and low cost. But, it fluctuates around the functioning point which causes losses in the output power, and the functioning point traces away from the peak point power which loses the way during fast weather (radiance) changes. That's why swing nearby to this peak point.

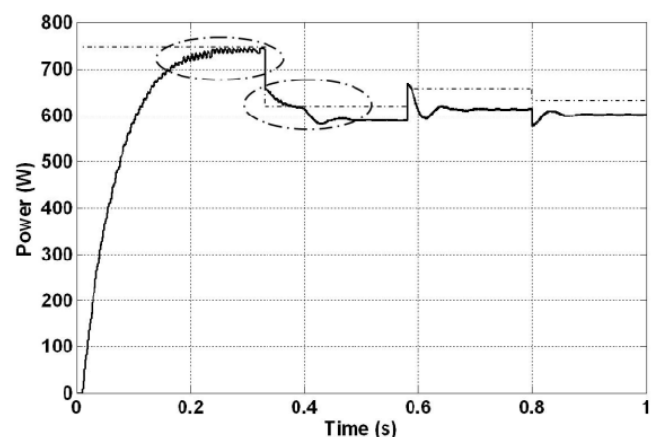


Figure 1. Photovoltaic output power of the conventional P&O approach [1]

Figure 1 illustrates the performance of the PV powered orthodox P&O MPE technique. The photovoltaic production power is imposed to track toward the MPE point. After attaining the best point, the photovoltaic output power fluctuates around the point. At the period 0.33 seconds, the radiation reduced; so, power deviates from the best value due to the problem aforementioned.

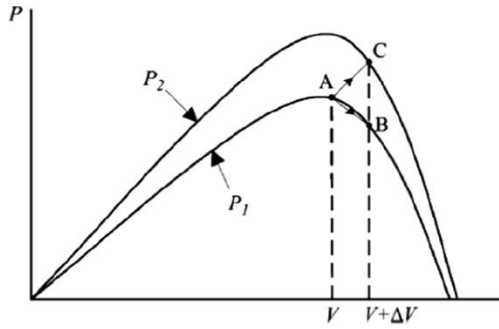


Figure 2. Change of orthodox P&O from MPE [2]

The existing basic P&O algorithm may exhibit erratic behaviour in fast varying atmospheric circumstances as a result of changing clouds. This limitation can be illuminated using Fig. 2 with two voltage versus power curves with changing radiance [12]. Assume that the functioning ‘A’ point is fluctuating around the MPP and a perturbation will move the functioning point toward the point ‘B’. Nevertheless, if the radiance rises rapidly to curve P2 power curve within singles sampling period, the functioning point will really move from the point ‘A’ toward the point ‘C’. This difficult occurs because the MPPT cannot recognize that power increment is the consequence of the rising irradiation and merely assumes that it is the outcome of changing the functioning point to the peak power. If the radiance is still rapidly rising, the MPE continuing to perturb to the right again and the functioning point continues to deviate from the real MPE until the sun radiation alteration slows. This condition can happen on the partly cloudy days, and the maximum power extraction is most problematic for frequent variation of the power in the extraction point.

The Divergence of the orthodox P&O from the possible power extraction under fast changing atmospheric circumstances that were defined in the previous section can be resolved by utilizing the PV voltage-current curve. As shown in this curve, in fixed radiation, when the voltage reduces (increases), the current is increased (decreased). Using this simple statistic, can be determined the divergence from the real MPE in rapidly varying atmospheric situations, as follows. If the voltage and power concurrently rises and current rises too, the calculation realizes that it is in fast varying weather situations and reductions of the voltage, in its place, it enhances. When the voltage and the power are rising concurrently and the current is reducing, calculation is in fixed radiation and raises the voltage. Hence the MPE tracking calculation evades

differing from the real MPE. The enhanced perturbation and observation flowchart is displayed in Fig.3.

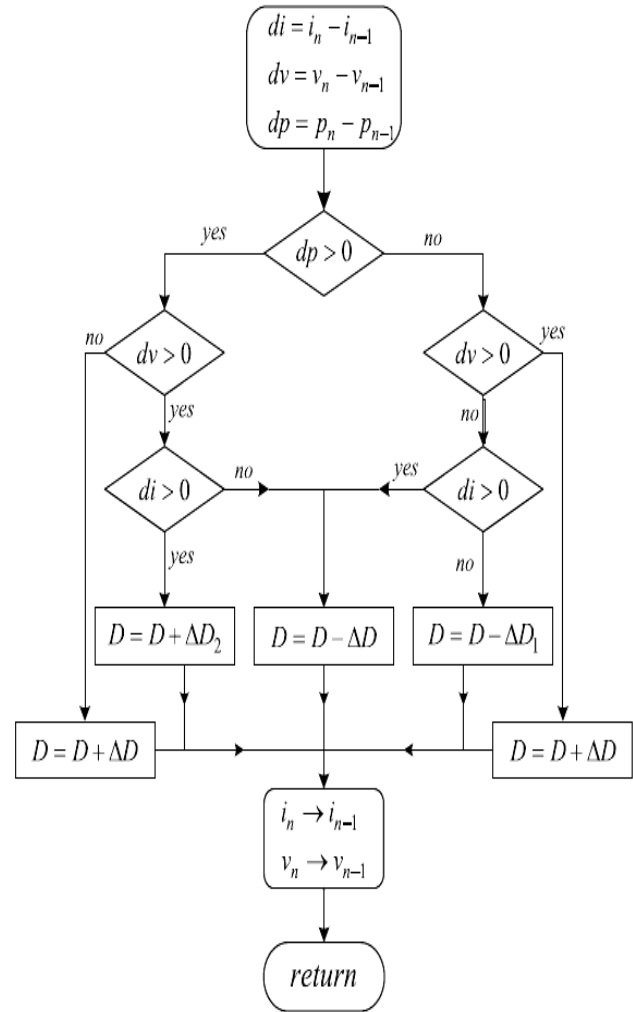
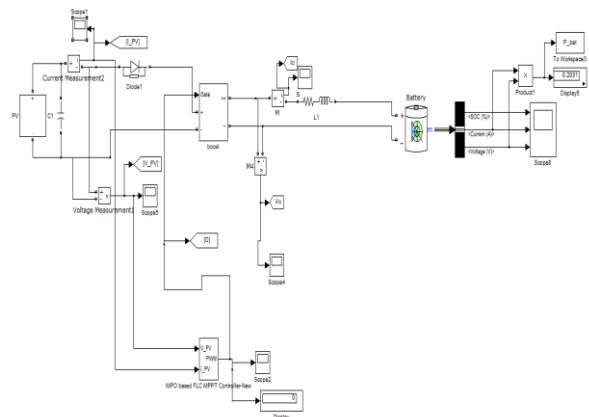
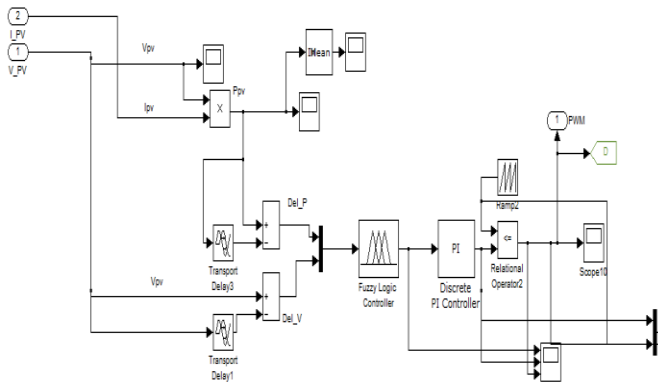


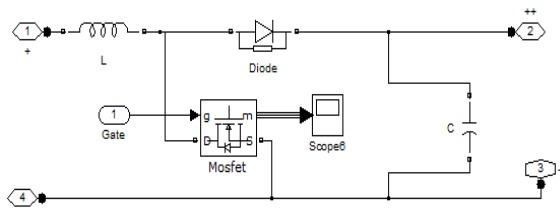
Fig.3 Flowchart of Improved P&O algorithm [2]



(a) Entire setup of the suggested structure



(b) Sub-view of FLC



(C) Direct current to Direct current step up converter

Fig.4 (a) proposed overall setup of the PV structure (b) Subsystem of the FLC controller (c) Boost converter

### 3 Suggested novel fuzzy system

The change of voltage output applied to the battery and converted into AC by using an inverter is the primary operation of the direct current to direct current step up converter. In this process duty-cycle level decreases or increases relying upon the extreme power. In addition, the controller variations the voltage level of output by varying the duty-cycle of the pulse width modulation signal, which traces the reference signal. A triangular reference signal is likened with the yield signal of fuzzy voltage reference to deliver a probably zero error signal. The fuzzy rules are developed from an improved P&O approach. This reference signal is adaptive, varying its shape according to climatic situations. The boost converter feeds the battery load with the greatest power.

The proposed entire block diagram presented in Fig.4 shows step up DC /DC conversion together with the MPE and the FLC. The creation of FLC was done utilizing Mamdani technique. The development of the rules, membership functions will be detailed in the

subsequent sections. The PWM (Pulse Width Modulation) changes its duty-cycle according to the controller signal.

### 4 Improved P&O based FLC Technique

In the FLC proposal, one should detect the foremost controller variables and regulate the sets that define the values of individually linguistic variable. The developed P&O searching algorithm is calculated to attain the deserves of conventional P&O simplicity and eradicate all aforementioned disadvantages. The variation of photovoltaic output voltage and output power are the dual input of the modified FLC approach. The increment of the reference output voltage of the fuzzy logic controller were fed into discrete Proportional and Integral (PI) controller through PWM control box to develop the pulse. The single output of dual inputs FLC are given in the equations from (1) to (3)

$$Del\_P = P(k) - P(k - 1) \quad (1)$$

$$Del\_V = V(k) - V(k - 1) \quad (2)$$

$$Del\_Vref = Vref(k) - Vref(k - 1) \quad (3)$$

The merits of this improvement in P&O are that the yield of the fuzzy based control changes the reference voltage only. Hence, the duty cycle of the DC to DC step up converter can further be regulated using a specific controller. Moreover, the step up converter MPPT controller ensures that the photovoltaic output power does not deviate from the possible power point during changing weather situations or variable load. The parameters of the input fuzzy logic are allocated into seven fuzzy subsets: zero (Z), negative big (NB), negative small (NS), positive big (PB), negative medium (NM), positive small (PS), positive medium (PM). These seven fuzzy subsets for dual input variables can produce forty-nine FLC rules, but the zero membership rules are reduced in a single rule which is only making a total of thirty-seven rules, instead of forty-nine. The Membership Functions (MF) of the output variables are nine-term fuzzy sets with trapezoidal shapes and classical triangular, positive double big(PBB), negative double big(NBB), negative big (NB), negative small (NS), negative medium (NM), zero (Z), positive medium (PM), positive small (PS), negative very small (NSL), positive big (PB) and positive very small (PSL). The fuzzy method exploited this is Mamdani method,





(del\_Vref) is normalized (-10 to 10). The fuzzy MF utilized as a part this design is mamdhani method. In the new fuzzy based MPPT Gaussian surface fuzzy MF is utilized. The triangular fuzzy MF for dual input and single yield are illustrated in the rule viewer and the corresponding surface diagram is revealed in Fig.7 and Fig.8 respectively.

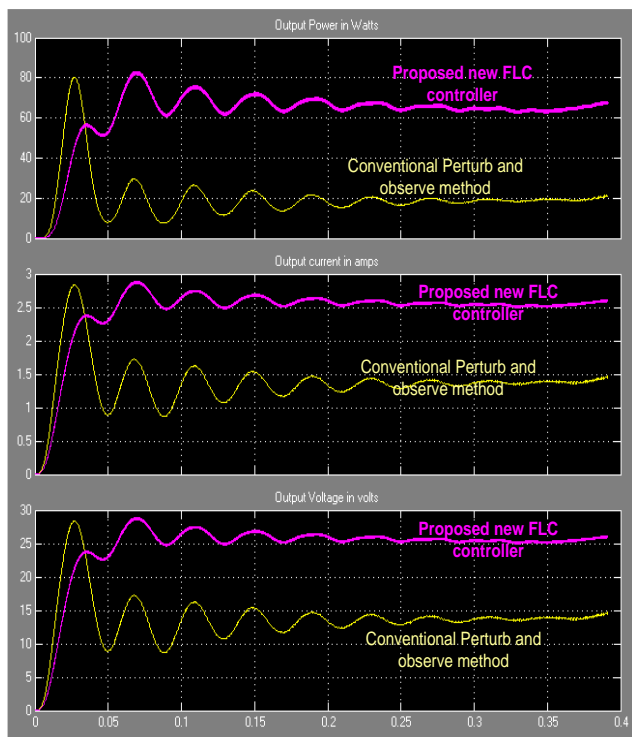


Fig.9 Converter output waveform of power, voltage

## 5 Simulation Results and Discussion

The simulation presented in Fig.9 belonged to the output of photovoltaic module and converter of power, voltage and current under steady temperature and irradiation conditions. The figures are clear that the limitation of orthodox P&O technique appeared where the reference losses the best point at abrupt irradiation varying. Moreover, at linearly irradiation changing, showed in Fig.10 is clear that the existing perturb and observation method lost the best point and caused fluctuations in the steady state while these drawbacks have been resolved for the developed novel fuzzy based maximum point power tracking approach. In both previous figures, the designed fuzzy based MPPT controller exhibited quicker reaction in the stable steady-state and transient response. Furthermore, the fluctuations disappeared, associated with the orthodox P&O approach. The fuzzy membership functions (MF) for dual inputs and solitary output are written as given in appendix.

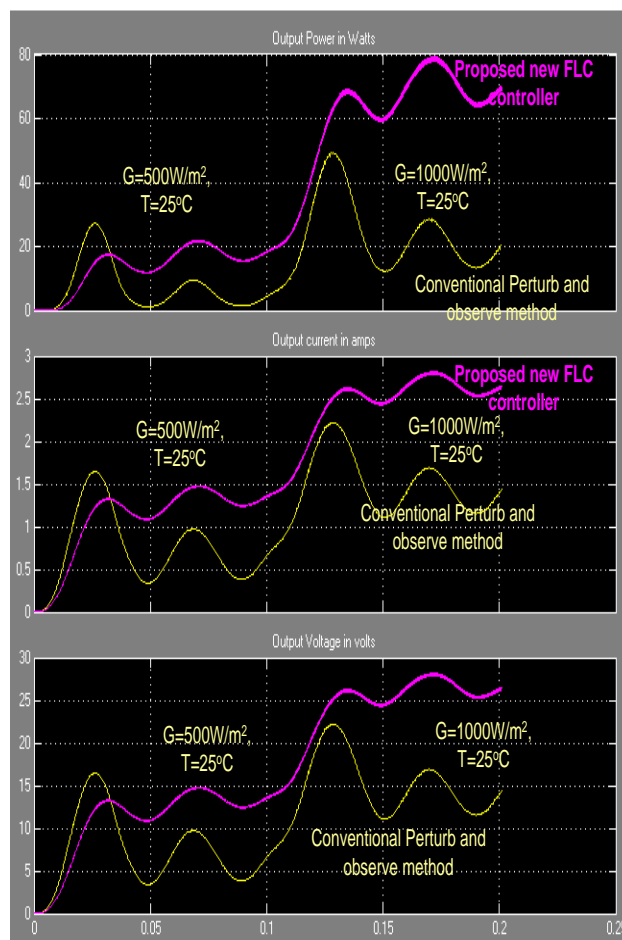


Fig.10 Converter output waveform of power, current and voltage under sudden varying irradiation conditions.

In appendix the proposed MPO based fuzzy logic controller programming coded has added. The code had developed by mamdani and centroid type of defuzzification method. The range of input 1 is varied from -10 to 10 it consists of seven MFs. The range of the input 2 is -0.5 to 0.5 it contains seven membership functions. The both input one and two are equal to MFs. The output of duty cycle varies the range from -10 to 10 it contains 11 MFs. if and else C programming code based written the entire program as shown on the Appendix and current under constant irradiation conditions.

## 6. Conclusion

This article has introduced an enhanced P&O based intelligent FLC (Fuzzy Logic Control) for greatest power point tracking under quickly changing weather circumstances. The proposed Maximum Power Extracting method was executed by fuzzifying the guidelines of enhanced P&O search approach to reduce its weaknesses, with a

relatively simple logic. A fast converging and accurate of MPE has been developed by FLC tracking during both changing weather circumstances and steady-state situation compared with conventional MPPT approaches. Simulink results were utilized to check the output of orthodox P&O and the proposed EPO-FLC approach. The outcomes of the developed EPO FLC MPPT exhibit less fluctuation around the maximum peak point under steady-state conditions, a faster converging speed, and no deviation from the peak point during changing weather circumstances. The viability and attainability of the developed FLC approach were evaluated with dissimilar simulation studies and compared with the existing MPPT techniques.

## 7 Conclusion - Future Scope

In this section, detailed two future scope of the proposed novel EPO based FLC MPPT system is described. 1. Instead of using a fuzzy logic controller may be possible to develop adaptive fuzzy logic based on maximum power extraction. When we try to use an adaptive fuzzy logic controller the tracking speed as well as accuracy increase. 2. Possible to mix with any of the optimization technique for better results.

### Appendix : MPO based Fuzzy logic controller

```
[System]
Name='paperFLC1'
Type='mamdani'
Version=2.0
NumInputs=2
NumOutputs=1
NumRules=37
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'
```

```
[Input1]
Name='Del__P'
Range=[-10 10]
NumMFs=7
MF1='NB': 'trimf',[-12.5892592592593 -
9.25925925925926 -5.92625925925926]
MF2='NM': 'trimf',[-10 -6.667 -3.333]
MF3='NS': 'trimf',[-6.667 -3.333 4.441e-016]
MF4='Z': 'trimf',[-3.333 -1.11e-016 3.333]
MF5='PS': 'trimf',[-0.0529100529100535
3.28008994708995 6.61408994708995]
MF6='PM': 'trimf',[3.333 6.667 10]
MF7='PB': 'trimf',[6.03207936507936
9.36507936507936 12.6950793650794]
```

```
[Input2]
Name='Del__V'
Range=[-0.5 0.5]
NumMFs=7
MF1='NB': 'trimf',[-0.619080952380952 -
0.452380952380952 -0.285680952380952]
MF2='NM': 'trimf',[-0.5 -0.3333 -0.1667]
MF3='NS': 'trimf',[-0.3333 -0.1667 -2.776e-017]
MF4='Z': 'trimf',[-0.1667 0 0.1667]
MF5='PS': 'trimf',[-2.776e-017 0.1667 0.3333]
MF6='PM': 'trimf',[0.164054497354497
0.330654497354497 0.497354497354497]
MF7='PB': 'trimf',[0.29361746031746
0.46031746031746 0.62701746031746]
```

```
[Output1]
```

Name='Del\_\_Vref'  
Range=[-10 10]  
NumMFs=11  
MF1='NBB':'trimf',[-12.1296296296296 - 9.62962962962963 -7.12962962962963]  
MF2='NB':'trimf',[-10 -7.5 -5]  
MF3='NM':'trimf',[-7.5 -5 -2.5]  
MF4='NS':'trimf',[-5.63492063492063 - 3.13492063492063 -0.634920634920634]  
MF5='Z':'trimf',[-2.18253968253968 0.317460317460316 2.81746031746032]  
MF6='PS':'trimf',[1.26984126984127 3.76984126984127 6.26984126984127]  
MF7='PM':'trimf',[2.97619047619048 5.47619047619048 7.97619047619048]  
MF8='PB':'trimf',[5 7.5 10]  
MF9='PBB':'trimf',[7.07671957671958 9.57671957671958 12.0767195767196]  
MF10='PSL':'trimf',[0.291040211640209 1.95164021164021 4.15343915343915]  
MF11='NSL':'trimf',[-3.99021164021164 1.38321164021164 0.929788359788357]

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