ISSN: 2349-7300
ISO 9001:2008 Certified
International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences (IJIRMPS)
Volume 3, Issue 1, February 2015

Novel Approach to Fuzzy Logic controller based Hybrid Solar/Micro Hydro/Bio-mass Generation, A Real time analysis (Barsoma Village, Ethiopia.)

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Abstract* — This research paper deals with the Fuzzy Logic Controller based hybrid solar/Micro-hydro/Bio-mass power generation system for Barsoma village. This deals with the design, analysis, and simulation. The study area has on average 5.4kwh/m2/d solar radiation, minimum flow rate of 4.06m3/s and 30MT per day coffee husk production. There are generally three types of loads (household, commercial and industrial) with total electric demand of 80KW. To satisfy this demand 30%, 40% and 30% is assumed to be contributed from Solar/Micro-hydro/Bio-mass respectively to produce 27KW from Solar system 96 modules, 305w panels having 38.4m2, area and 4.6kwh/m2/d solar insulation is required for Micro-hydro to produce 36KW, 1.0m3/s flow rate, 8.1m head, 50% efficiency and 0.6m weir length, 2.0m^2 canal area, 103m penstock length is taken. To produce 27KW from Bio-mass system, only 10% of the annual coffee husk production (10,651.896 MT) is used. The fluidizing velocity, coffee husk feed rate, gas flow rate, gasifier height and gasifier cross-sectional area are calculated as 0.5m/s, 21.6kg/h, 0.01Nm^3/s, 2.1m and 0.02m^2 respectively. To use the power economically, Fuzzy Logic Controller is used. The controller monitors the demand and the available sources, and then switches appropriate power supply according to the written rules. The components of the hybrid system are modeled in Mat lab / Simulink. The simulation results clearly explains and gives an idea about how the controller can supply the intended power demand in different cases, i.e., the output power from controller is varying from 0.1 p.u to 0.95 p.u to satisfy the electric demand of consumer .

Key-Words: - **Bio-mass, Fuzzy Logic Controller, Gasification, Hybrid, Insulation, Mat lab / Simulink, Micro-Hydro and Solar energy.**

I. INTRODUCTION

The World Energy Council proposed a target of a minimum of 500 kWh per year for everyone in the world by 2020, but the current per capital consumption of Ethiopia is 25 kWh per person per year [1]. This shows that the access of electricity in the country is very low. About 85% of the population of Ethiopia is living in rural areas, where access to modern electricity is difficult [2]. The communities concerned for this study are settled farther away from the national grid and are sparsely populated, which makes extending the national grid is uneconomical because of the high cost of transmission and and distribution as well the very low load factor. When the issue of electrification is raised, the key issue and the problem that needs to be addressed the question of affordability and pollution of the environment. Ethiopia has huge renewable energies such as micro-hydropower, solar, geothermal, biomass and wind that have not yet been assessed and accessed for rural electrification. Though Ethiopia is having huge renewable energy potential, the 85% of the population are not yet electrified. This research paper a standalone hybrid solar/micro-hydro/Bio-mass power system is proposed for rural areas. This type of hybrid system plays great role in protection of the environment for the countries such as Ethiopia where majority of their people are participating in coffee production.

II. POTENTIAL RESOURCES AND ASSESSMENT OF RESOURCE AT BARSOMA

A. Solar radiation (kwh/m^2/d)

The sunshine hour which is taken from Jimma metrology center is converted in to global solar radiation using Angstrom estimation model. Finally the average and minimum kwh/m2/d of the study area is 5.4 and 4.60 respectively. In this case the minimum value is taken (4.60kwh/m2/d).

B. Micro-hydro flow rate (m^3/s)

The flow rate of the study river (Naso River) is calculated using simple area ratio method from Gilgel Gibe III. As a result of the empirical formula the minimum and maximum flow rate of Naso River is 4.06 m3/s and 69 m3/s respectively. The minimum value (4.06 m3/s) is required for designing.

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C. Coffee husk assessment (metric tons)

The average annual coffee seed production of the study area is 14,794.3 metric tons per year. Experimental researches highlights and defines clearly that the coffee seed to coffee husk ratio is 52%: 48%, then accordingly 14,794.3metric tons of coffee seed and 14,202.528 metric tons of coffee husk has been produced from 28,996.828 metric tons of coffee fruit. If 25% of coffee husk produced is assumed to be wasted, the rest 75% (10,651.896 metric tons) which is 30 metric tons per day of the produced husk is dumped (thrown) without any economic value to environment more over this will a national waste and pollution, hence must be clearly utilized, this research papers clearly incorporate the efficient usage of the above resource.

III. DESIGNING HYBRID SYSTEM COMPONENTS

A. Energy demand Profile a detailed analysis

The first step in designing power system is to determine the total power consumption of the study area. The size and cost of hybrid system components are highly influenced by the size of electrical loads. The necessary steps to estimate electricity required in the study area is to list all electrical appliances, estimate energy consumption, multiply the by the number of hours used each day and add up the watt hours for all appliances.

Accordingly the electric energy consumption of Households, Commercial loads and Industrial loads are 658.495KWh, 9.284KWh, 2.250KWh respectively. Total annual energy consumption per year = 670.029 KWh x 365 = 244.56MWh. Average load demand per hour is 27.9KW.

$$\text{Peak load} = \frac{\text{average load demand } (L_D)}{\text{load factor(LF)}},$$

Assume LF is 57%, PL = $\frac{LD}{LF}$ = 48.9KW. Installed capacity (IC) = peak load + loss, assuming loss is 10% of peak load, 4.89KW [3]. Installed capacity(IC) = peak load + loss IC = 48.9KW +4.89KW = 54KW. Therefore the total electrical energy demand of Barsoma Village for the base year 2014 G.c is 54KW. During designing to forecast for few years is must, therefore the demand is forecasted for 10 years using sheers method. Finally the total electrical power demand of Barsoma Village for the year 2024 G.c will be 80KW.

B. PV system designing and Sizing

The total electrical power demand of Barsoma Village for the future demand (by 2024 G.c is 80KW). 30% of the total power demand is covered by, (0.3 x 80KW= 24KW), solar PV system. Assuming the system power loss is 10%, 2.4KW. The total power generation capacity of the solar PV system is 27 KW. To calculate number of parallel strings (Np), assume (system voltage is 12V (Vm), a string with 4 modules (Ns), rated solar power is 305W (Pm).

$$Np = \frac{\text{Peak power}}{Pm * Ns} = \frac{27kw}{305 * 4}$$

Therefore total number of modules of solar system, can be calculated as N = Ns*Np = 24*4 = 96 modules. Assume a single solar module is having Am; $0.4m^2$ cross sectional area [4] the total area required for the solar panels is possible to calculate as in the following equation. Ap = Am*N = 0.4*96 = 38.4m2. The size of the Inverter is determined by the AC load required with consideration for surge power. inverter size should be 25-30% bigger than the total watts of the loads the specification inverter date obtained. Maximum AC load is 27kw, inverter constant is 1.25. Therefore Inverter rating is maximum AC x 1.25 = 27*1.25 = 33.8KW. 33.8KW pure sine wave inverter is recommended.

C. Micro-hydro system designing and sizing

The design parameters of Micro-hydro as per power requirements of the system are H=9m, assume 10% head loss, h=9-0.1*9=8.1m, designed flow rate is $1.0m^3/s$, efficiency of small turbine = 0.5 [5].

The total power demand of the year 2024 G.c is calculated as 80KW. In designing the hybrid power system 40% (32KW) of the power demand of the village is assumed to be calculated as

P = ηgQh =0.5*9.81*1*8.1= 40KW.

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D. Bio-mass system designing and sizing

The total electrical power demand of Barsoma Village for the year 2024 G.c is calculated as 80KW. In designing the hybrid power system 30% (24KW) of the power demand of the village is assumed to be covered by Bio-mass power system. Assume 10% of system loss which was 24*0.1=2.4KW, Generator capacity = 24+2.4 = 26.4KW~ 27KW. Generating capacity of the coffee husk is estimated by the following empirical formula.

$$P_{bi}(kw)=\frac{10\%*25\%\ of 10{,}651.896T/y*1000kgs}{2kgs\frac{husk}{kwh}*16h*300d/y}$$

The total coffee husk production of Gomma Wereda is 10,651.896 MT/year). Assumed gasification efficiency is 25% [5] and 10% of annual coffee husk production, 16 working hours per day, 300days per year and 2 Kgs of husk is needed in an hour to produce 1 KW of power. [1 Metric tons = 1000kgs]. Using the above empirical formula 28kw can be generated from Biomass.

IV. PROPOSED MODEL USING OF FUZZY LOGIC CONTROLLER FOR THE HYBRID SYSTEM

The proposed hybrid system consists of solar, micro-hydro renewable combination along with a complementary bio-mass power generator which acts as the supplement. The capability of the electric generation hybrid systems is to satisfy the power demand on the atmospheric conditions. Fuzzy Logic Controller is used to use the power efficiently and to serve the power demand of customer. The controller looks first at the load and switches the appropriate source to meet the demand from the customer side. The generator used for the Bio-mass is dual fuel engine generator b/c if in case there will be shortage of input Bio-mass, it will be possible also to use diesel. There is no need of battery storage, charge controller.

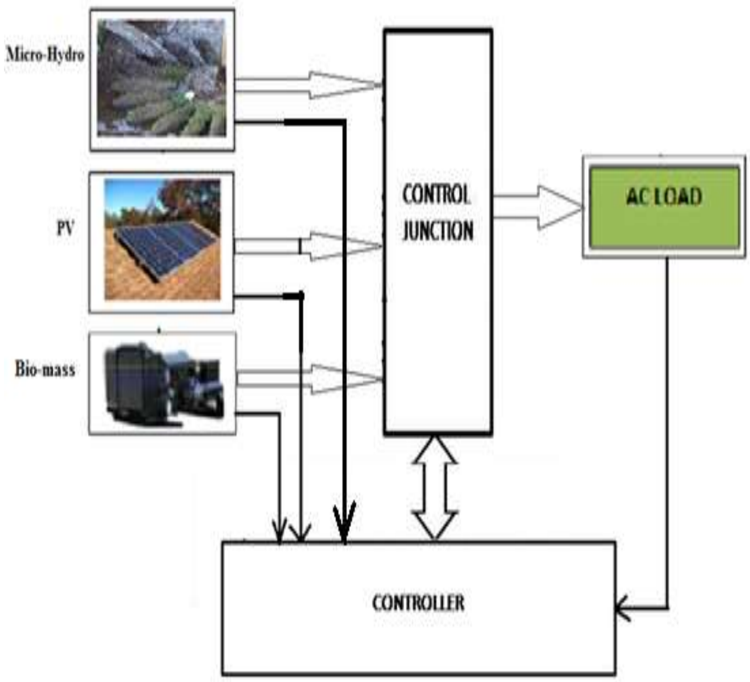

Fig. 1 Proposed block diagram

Basically these operation modes are determined by the energy balance between the total generation and the total demand. A comprehensive controller is essential to efficiently manage the operation of the generation subsystems ie ac. The important requirement of the standalone hybrid system is the availability of renewable energy resources, and then the combination has to be formulated.

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A. Fuzzy Logic Controller algorithm

Fuzzy logic controller is an intelligent tool to manage the integrated energy sources in such a way that it meets the load requirement under varying load conditions. The procedures in making the controller designs are 1.setting the constraints, 2.Assigning the linguistic variables and setting the rules for the controller. In this research work the FLC has four inputs and one output. The input linguistic variables of FLC are Solar power (Sp), Micro-hydro power (MHp), Bio-mass power (Bp) and Power demand (PD) where as the single Output linguistic variable is out power (Po). Each input linguistic variable has three linguistic values called Low, Medium and Large and the output linguistic variable has MHp only, MHp+Sp, MHp+Bp, MHp+Sp+BP linguistic values. Triangular membership function for Justification, Mamdani inference system for rule processing and center of gravity for De-fuzzy analysis and process by fuzzy logic is used. A typical fuzzy system consists of a membership functions, rule base, inference procedure and rule viewer which were explained in the following sections. After giving membership function for each input output linguistic values and generating the possible operational rules then the next step is to evaluate the rules of the controller for the input values if the output is appropriate or not. To see the overall performance the hybrid system, the components are assumed to produce random signal.

B. Fuzzy inference model

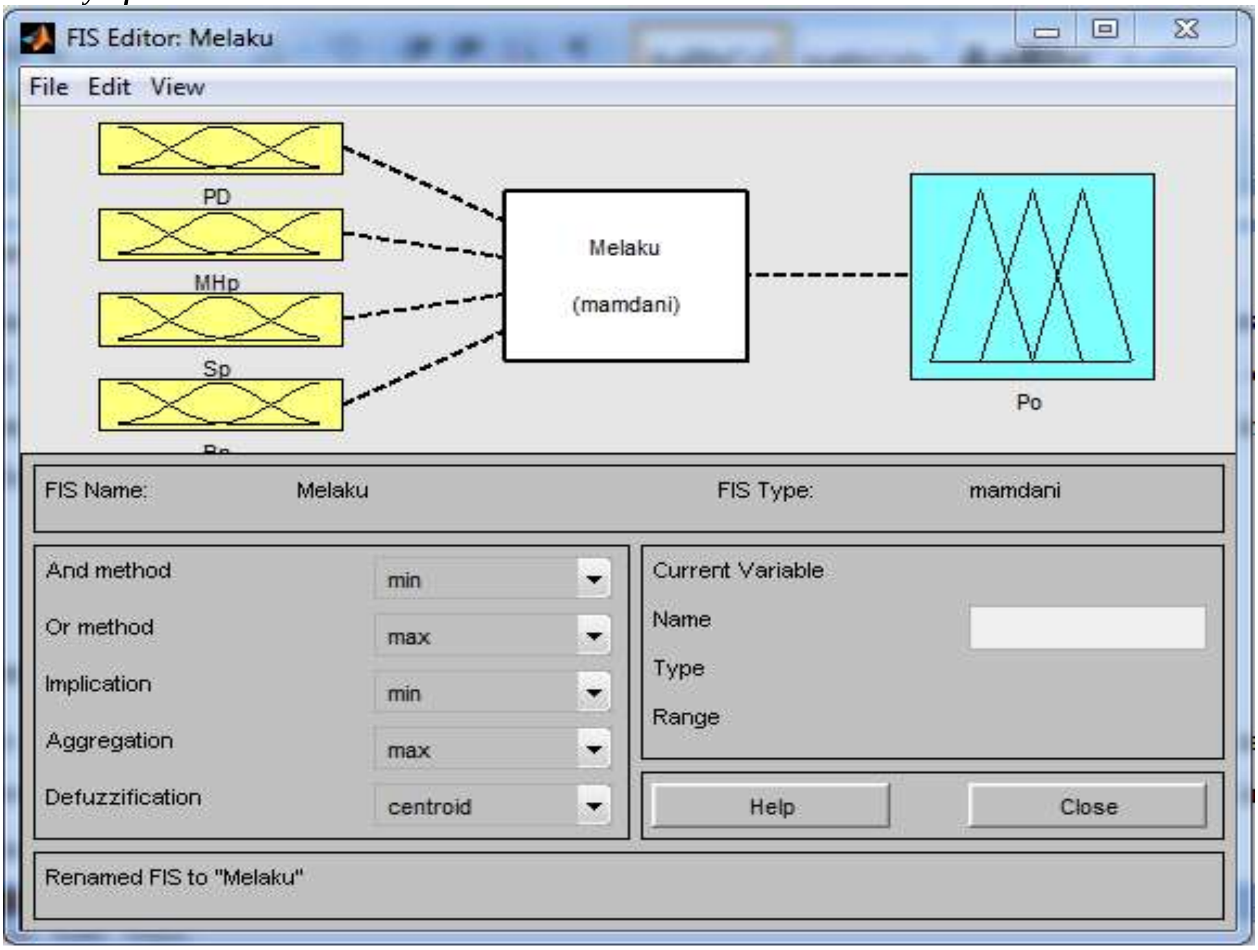

Fig.2 Fuzzy Inference Model

C. Membership function of power demand, PD

The power demand (PD) is one of the input linguistic variables having three linguistic values called Low (0 15 30), Medium (20 40 60) and Large (40 60 80).

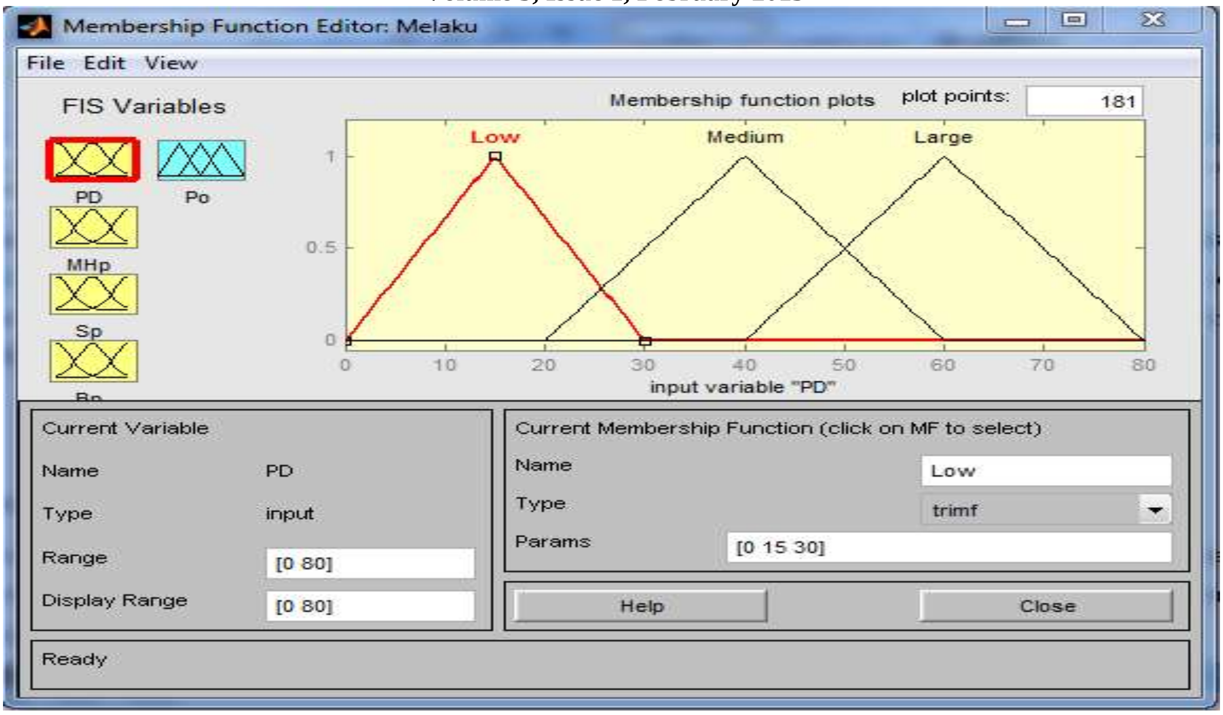

Fig 3 Membership function of power demand real time simulated version

D. Member ship function of Micro-hydro, MHp

Micro-hydro power, MHp is the second input linguistic variables having three linguistic values called Low (0 7.5 15), Medium (10 17.5 25) and Large (20 28 36).

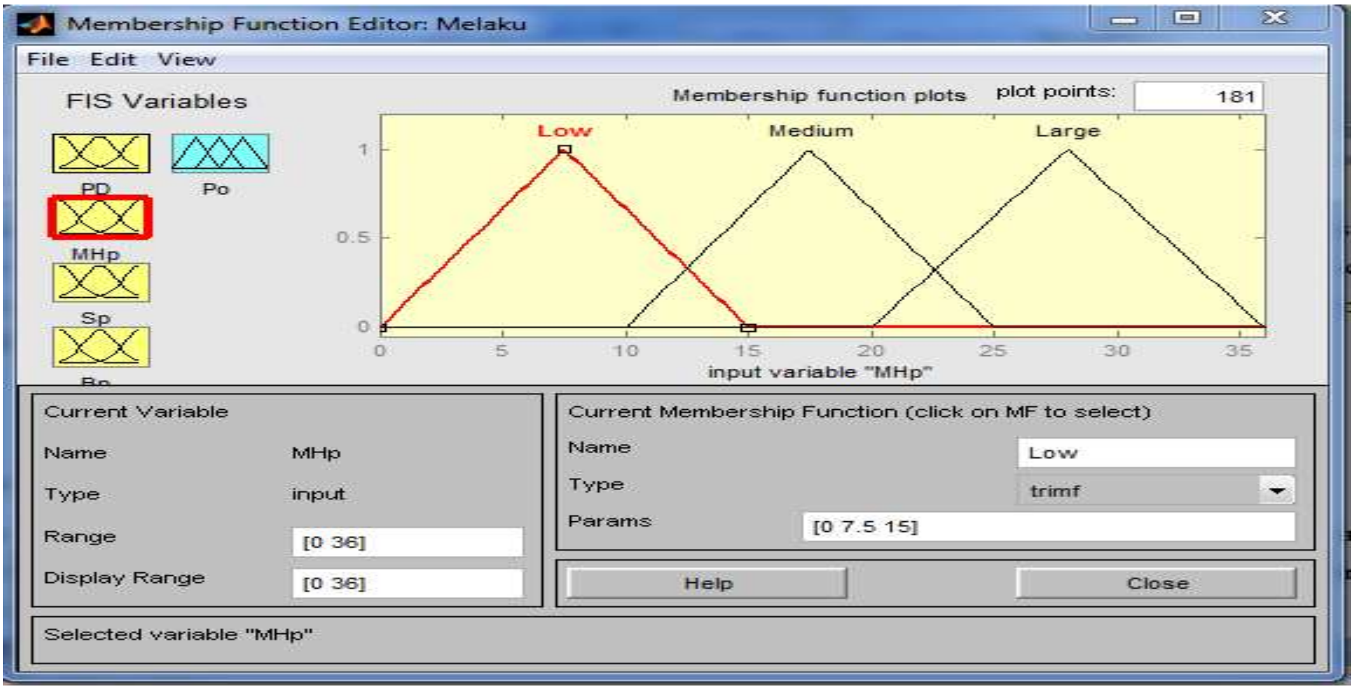

Fig 4 Real time analysis of Member ship function of Micro-hydro

E. Member ship function of solar power, Sp

Solar power, Sp is the third input linguistic variable having three linguistic values called Low (0 5 10), Medium (5 12.5 20) and Large (15 21 27).

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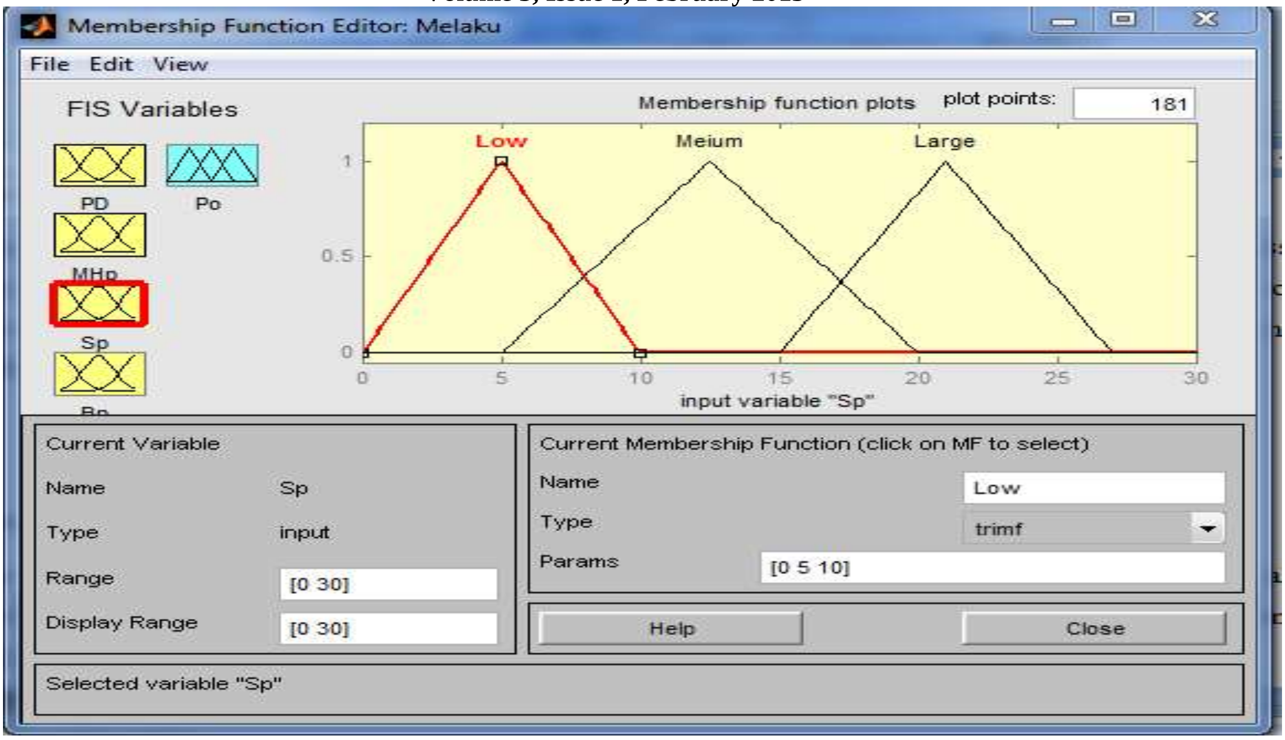

Fig 5 Member ship function of solar power

F. Member ship function of Bio-mass power, Bp

Bio-mass power, Bp is the fourth input linguistic variable having three linguistic values called Low (0 5 10), Medium (5 12.5 20) and Large (15 21 27).

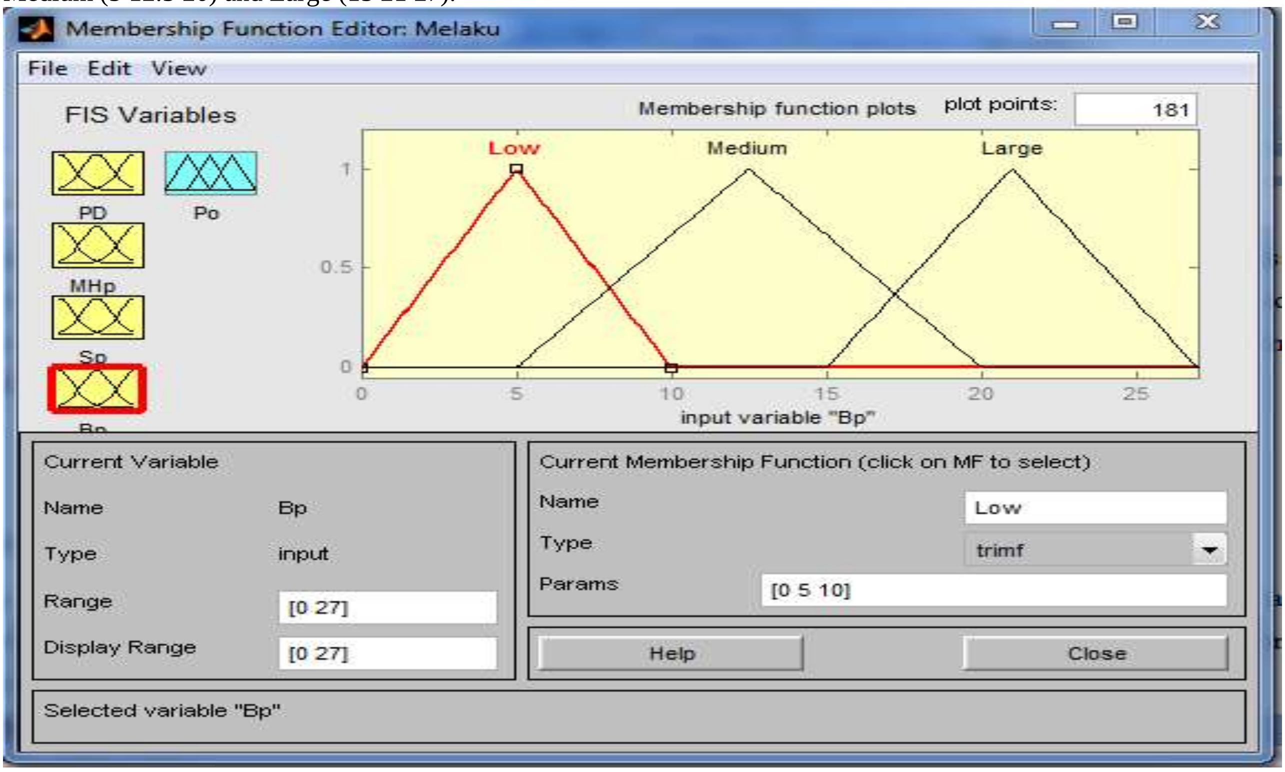

Fig 6 Member ship function of Bio-mass power

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ISO 9001:2008 Certified
International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences (IJIRMPS)
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G. Member ship function of output power, Po

Output power, Po is the only output linguistic variable having three linguistic values called MHp only (0 12.5 25), MHp+Sp (20 30 40), MHp+Bp (30 45 60) and MHp+Sp+Bp (50 65 80).

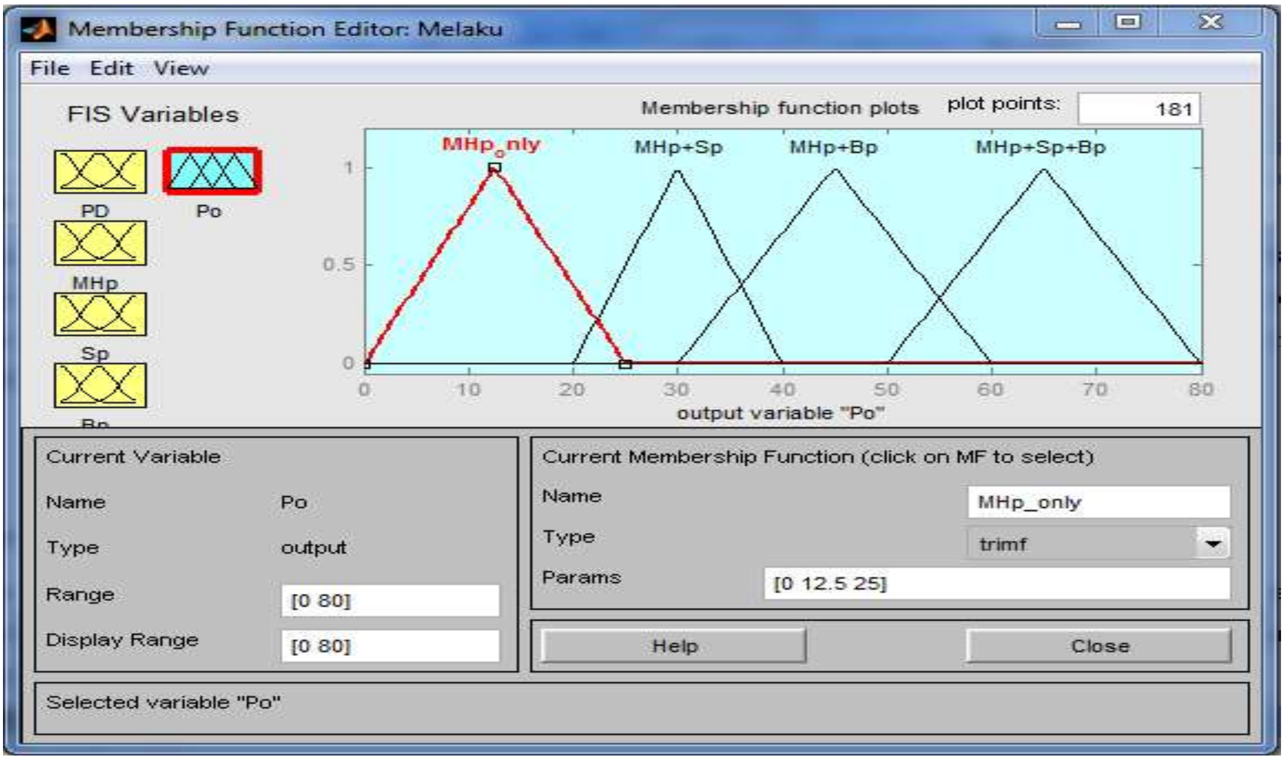

Fig 7 Member ship function of output power

H. Real time modeling of Fuzzy Logic Control Rules

Here is the model of fuzzy logic controller having four inputs and one output. In the control box, a set of rules have been written. The system was operated in accordance to the rules sets.

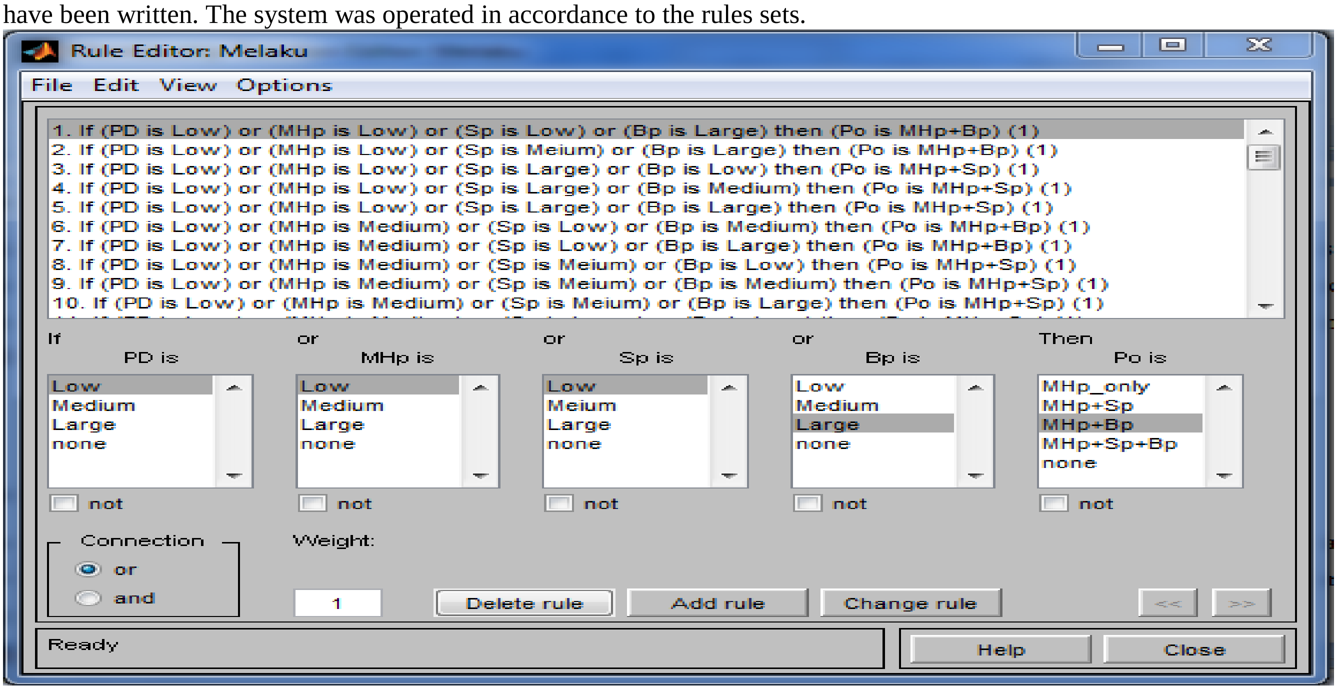

Fig 8 Fuzzy Logic Controller rule editor

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I. Rule evaluating or Viewer

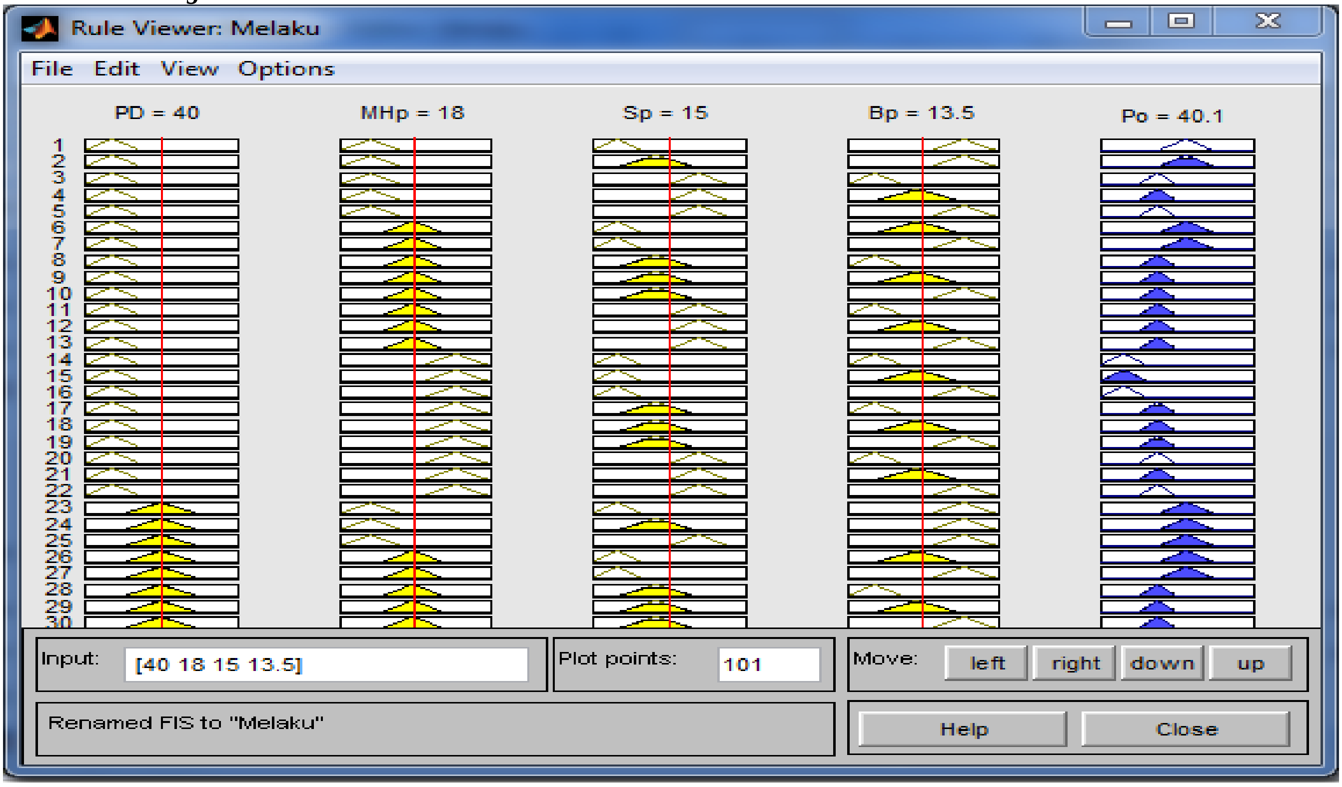

Fig 9 Rule viewer

V. OVERALL FUZZY LOGIC CONTROLLER SYSTEM

The solar power, Micro-hydro power, Bio-mass power and demand power are the input parameters of the controller. PD, MHp, Sp and Bp indicates the demand power from customer side, power from Micro-hydro, power from solar system and power from Bio-mass respectively. The power coming from each component of power sources is assumed to Gaussian random signal generator. The multiport conditional switch will take an action according to the rules written in fuzzy logic controller.

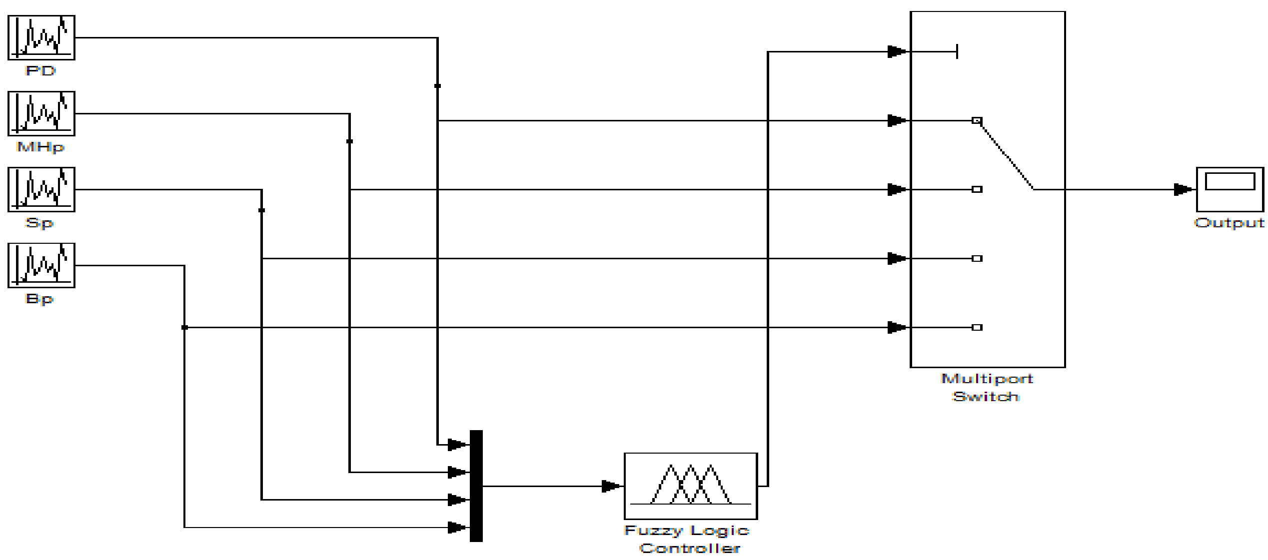

Fig 10 over all hybrid system

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ISO 9001:2008 Certified
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VI. PERFORMANCE EVALUATION OF THE DESIGNED CONTROLLER

To evaluate the designed Fuzzy Logic Controller, it is possible to think different operating conditions, such as if the sunshine is low, flow rate is high and coffee husk is Medium and other conditions.

A. Case study one

If for example the demand power PD is 20kw, MHp is 13kw, Sp is 10kw and Bp is 0kw, and then the output power of Fuzzy Logic Controller is indicated as in fig 11.

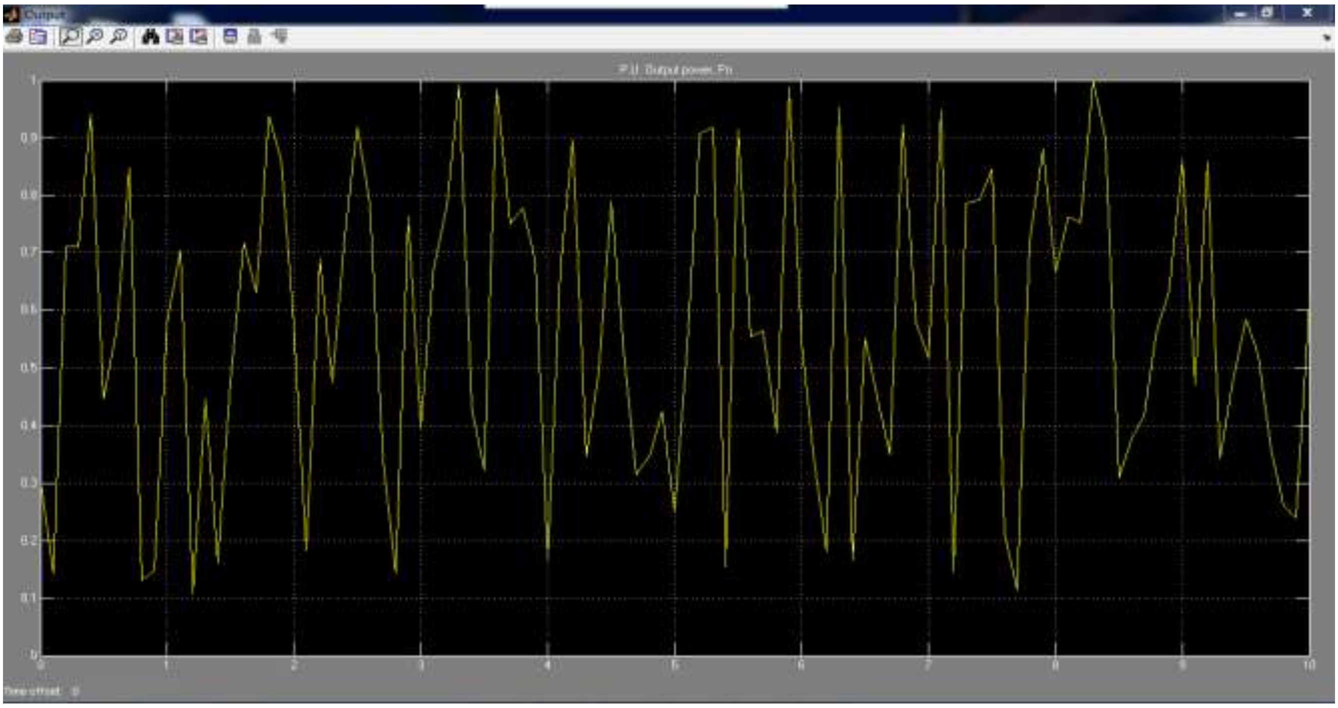

Fig 11 Simulation result of Fuzzy Logic Controller for case one

B. Case study two

If for example the demand power PD is 40kw, MHp = 30kw, Sp = 0kw and Bp = 10kw, then the output power of Fuzzy Logic Controller will be indicated as in fig 12.

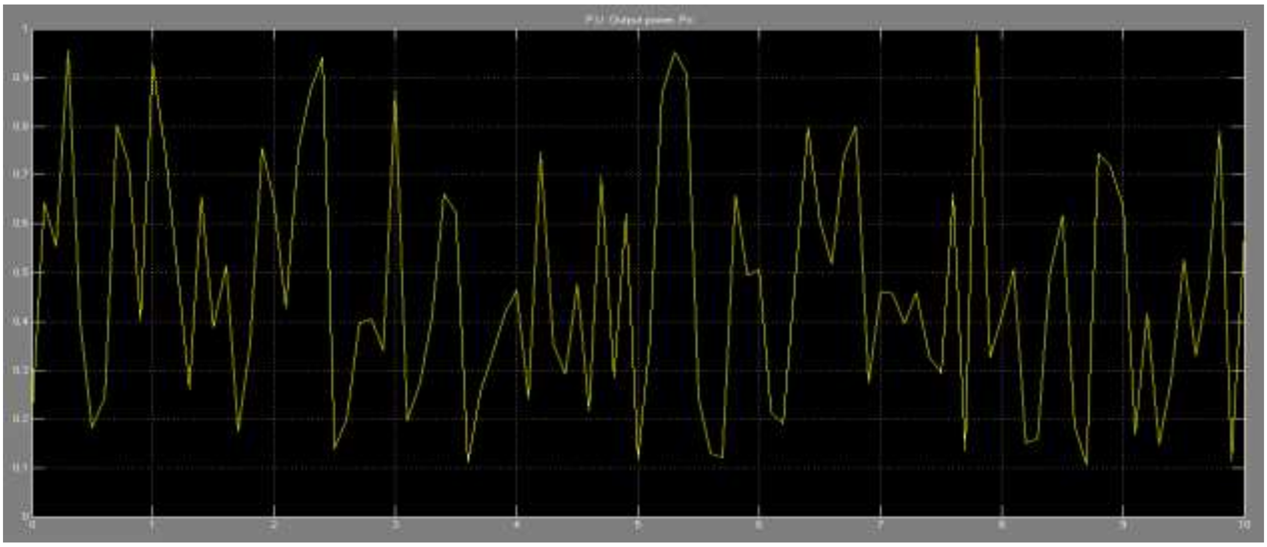

Fig 12 Simulation result of Fuzzy Logic Controller for case two

ISSN: 2349-7300
ISO 9001:2008 Certified
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C. Case study three

If for example the demand power PD is 50kw, MHp = 15kw, Sp = 27kw and Bp = 20kw , then the output power of Fuzzy Logic Controller is indicated as in fig 13.

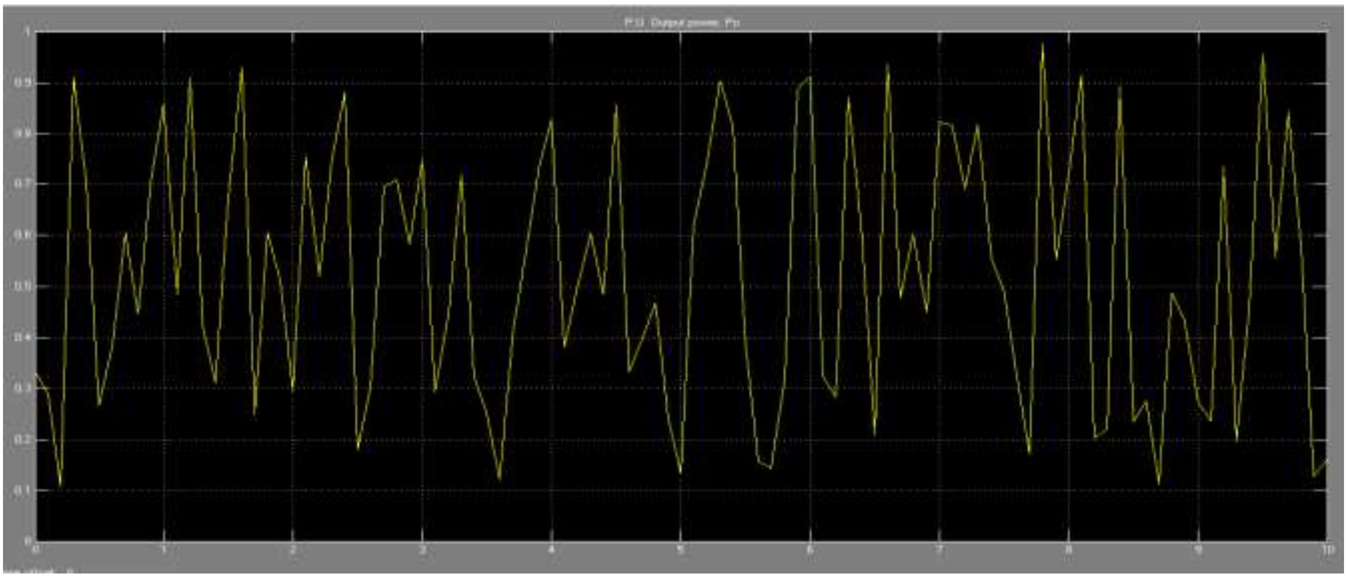

Fig 13 Simulation result of Fuzzy Logic Controller for case three

D. Case study four

If for example the demand power PD is 70kw, MHp = 30kw, Sp = 27kw and Bp = 25kw, then the output power of Fuzzy Logic Controller is indicated as in fig 14.

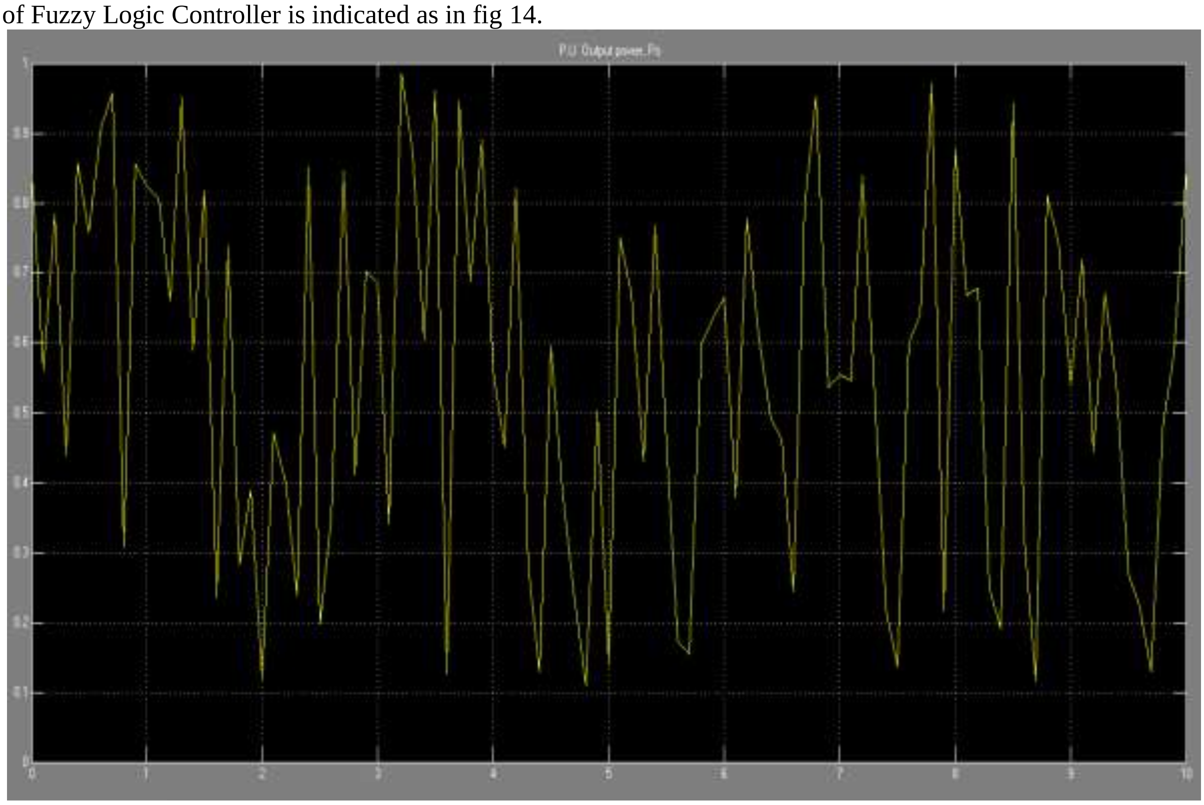

Fig 14 Simulation result of Fuzzy Logic Controller for case four

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ISO 9001:2008 Certified
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VII. RESULTS AND DISCUSSIONS

In case study one the demand power is 20KW. The p.u value of this value is 0.25. The out power from the controller in the scope indicates around 0.28. This is to say for the demand (20KW), the appropriate output power from the controller is 22.4KW which is correct. In case study four, the demand power is 70KW. The p.u value of this value is 0.875. The out power from the controller in the scope indicates around 0.84. This is to say for the demand (70KW); the output power from the controller is only 67.2KW. As it was possible to see the output power of the Fuzzy Logic Controller on the above four cases of the simulation results, the output power varies between 0.1 to 0.95 p.u (8kw to 76kw) for different input values of the hybrid power sources.

VIII. CONCLUDING REMARKS

After the detailed study and the analysis we can draw the following conclusion viz the solar radiation, flow rate and coffee husk production of the Barsoma village are 4.60kwh/m2, 1.0m3/s and 30MT/day respectively. The load profile of the village (305 household) is found as 658.495KWh, 9.284KWh, 2.250KWh per day for Households applications, Commercial loads and Industrial loads respectively. During the calculation for lighting (100% of household), Radio (80% of household), TV (60% of household), refrigerator (30% of household) is assumed. Elementary school and health clinic Commercial loads and coffee washing machine and water pumping motors are considered. Total energy consumption of the Barsoma village per year is 244.56MWh. During designing the energy consumption of the village is forecasted for 10 years using appropriate formula from 244.56MWh per year (54KW) to 573.84MWh per year (80KW) from the base year. According to the load assessment conducted, the total electric demand of Barsoma village was 80KW. To handle the 80KW demand, Solar/Micro-hydro/Bio-mass, 30%, 40% and 30% is contributed respectively. The intelligent controller is used to make intelligent decision by sensing the type and amount of resource available, and then it selects the appropriate alternative source. The simulation results tell, the controller can supply the intended power demand in different cases, i.e., the output power from controller is varying from 0.1 p.u to 0.95 p.u to satisfy the electric demand of the consumer.

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ISSN: 2349-7300
ISO 9001:2008 Certified
International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences (IJIRMPS)
Volume 3, Issue 1, February 2015

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