Fuzzy Logic Optimization Algorithm for Automatic Generation Control of Multi Area Power System Using MOSFET Based PWM Inverter

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***Abstract*— Energy is the defining need of the 21st century & electrical energy has replaced most of the other conventional sources of the energy due to its cost, reliability & other advantages. The demand for electricity is rapidly increasing & thus integration of renewable energy generation plants in a multi area generation setup is required. This work aims at optimization of operational cost of power generation in a multi area power generation System comprised of various types of power generation setups such as non-renewable ones, Thermal & nuclear as the renewable ones such as solar or wind. The proposed work aims at development of fuzzy logic controller with corresponding embedded hardware to demonstrate multi area power generation with priority to renewable energy optimization of generation cost depending upon the varied load conditions. This work demonstrates on embedded 'C' controlled hardware controlled vid fuzzy logic implemented in Matlab over connection on RS232 port.**

Keywords*— *Multi area power generation, Fuzzy logic, Matlab, Data Aequitsiton tool box, Dual converter.

I. Introduction

(i) Fuzzy Logic:- Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false. By contrast, in Boolean logic, the truth values of variables may only be the integer values 0 or 1. It is based on the observation that people make decisions based on imprecise and non-numerical information, fuzzy models or sets are mathematical means of representing vagueness and imprecise information, hence the term fuzzy. These models have the capability of recognising, representing, manipulating, interpreting, and utilising data and information that are vague and lack certainty.

Fuzzy logic has been applied to many fields, from control theory to artificial intelligence. Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the way systems behave in the real world.

Additional benefits of fuzzy logic include its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity. "If you don't have a good plant model, or if the system is changing, then fuzzy will produce a better solution than conventional control techniques," says Bob Varley, a Senior Systems Engineer at Harris Corp., an aerospace company in Palm Bay, Florida. You can create a fuzzy system to match any set of input-output data. The Fuzzy Logic Toolbox makes this particularly easy by supplying adaptive techniques such as adaptive neuro-fuzzy inference systems (ANFIS) and fuzzy subtractive clustering.

Fuzzy logic models, called fuzzy inference systems, consist of a number of conditional "if-then" rules. For the designer who understands the system, these rules are easy to write, and as many rules as necessary can be supplied to describe the system adequately (although typically only a moderate number of rules are needed).

(ii) **Automatic Generation Control of Multi Area Power System**

One of the most important components in the daily operation of an electrical power system is the scheduling and control of generation. This function is the primary concern of the energy control centre and largely provided by an automatic generation control (AGC) program implemented as part of the energy management system (EMS).

Although the process is highly automated power system dispatchers can interact with it, by monitoring its results and inputting data that reflect the current operating conditions. In general, electrical power systems are interconnected to provide secure and economical operation. The interconnection is typically divided into control area with each consisting of one or more power utility companies. Control areas are connected by transmission lines commonly referred to as tie-lines and the power flowing between control areas is called tie-line interchange power. One of the main responsibilities of each control area is to supply sufficient generation to meet the load demand of its customers, either with its own generation sources or with power purchased from other control areas.

The main part of power system operation and control is to maintain continuous supply of power with an acceptable quality, to all the consumers in the system. The system will be in equilibrium, when there is a balance between the power demand and the power generated.

II. LITERATURE REVIEW

In this paper a number of decentralised and centralised PI and Model Predictive Control (MPC) based algorithms were proposed for the purposes of Automatic Generation Control (AGC) in Multi-Terminal HVDC (MTDC) grids. The use of voltage offsets was also proposed as an additional control variable to improve performance. The paper discusses how this approach improves the sharing of secondary reserves and could assist in achieving EU energy targets for 2030 and beyond.[1]

In this paper the gravitational search algorithm is used to obtain optimum gains of the PIDF controller for problem of automatic generation control (AGC). First GSA is illustrated in detail and therefore investigated power system under study. The results of simulation emphasize the effectiveness of the GSA. The PIDF controller which is tuned by GSA has been strongly proposed for automatic generation control. [2]

A multi-level power system is considered in the paper with wind-energy generation in area-1. The contingency situations of sudden loss of generation and sudden loss of loads are simulated for a two-area system with one of the areas having Wind-turbine generator. The results show that the frequency deviation and the voltage profiles are within the limits in the two situations. Coordinated scheduling of power is necessary to maintain the system parameters under control. [3]

This paper applies the ACO based fuzzy controller to the SEDC Motor. The fuzzy rules are optimized off line, while the parameters of the fuzzy controller are tuned on line. By a comparison the Hybrid Fuzzy ACA Controller, ACA and Fuzzy logic controller, the Hybrid Fuzzy-ACA Controller is not only more robust, but can also achieve a better static and dynamic performance of the system. [4]

A simulation study of single area, two areas and three areas as a multi system with automatic generation and control is carried out with models developed in SIMULINK MATLAB. The system experiences frequency drift following a load disturbance and it is mainly due to the mismatch between the electrical load and the mechanical input to the turbine. [5]

In this work, a type 1 fuzzy controller is used for controlling the load frequency of the single area non-reheat thermal power plant. A 1% step load perturbation is applied in the load demand of the power plant and analysis the system responses in terms of settling time, peak overshoot and peak undershoot. So, it is necessary to maintain the system frequency is to be constant. [6]

This paper is ratified with a novel hybrid DECRPSO algorithm optimized FPID controller used in both the areas of a mutually connected hydro-thermal power system to minimize the ACE. To achieve better regulation over tie-line power and frequency deviation, the gains of the FPID controller are optimized by PSO, CRPSO and hybrid DECRPSO algorithms. [7]

In this paper, the optimal load frequency control (LFC) of interconnected power systems is investigated. The impact of LFC control method on the fluctuations caused by step load disturbance is examined; also the effect of LFC controller is analyzed. The Proportional-Integral Derivative (PID) controller parameters of the investigated LFC model are optimized by different techniques. An application of new approach based on hybrid Genetic Algorithm and Particle Swarm Optimization (HGA-PSO) to solve LFC problem is developed. The proposed hybrid GAPSO algorithm is first applied to the two-area interconnected power system and then extended to the large three-area 9-unit interconnected power system model. The comparative study demonstrates the validity and the potential of the proposed approach and shows its robustness to solve the optimal LFC problem.[8]

The present article developed a new approach for the LFC of a single-area power system as an extension of the TDF-IMC scheme. The inner and outer loop controllers were computed with the help of a predictive model, observed from the responses and performance indices that the proposed configuration generates better results with the nominal and perturbed parameters. Furthermore, it was observed that the proposed scheme gives better transient and steady state performances with the external load disturbance. [9]

Comparison of the settling times of MSMA power system using ADRC and PID as secondary controllers is shown in Table 1. From the Table, it is observed that the settling time using ADRC is less compared to PID Controller. Not only settling time but also overshoots/undershoots remain very low by using an ADRC Controller which is observed from Figs 8 - 25. Settling time remains same for both the ADRC and PID controllers for different load changes in the power system. [10]

This paper investigates the performance of automatic generation control of three area thermal power system. To demonstrate the effectiveness of proposed controller, evolutionary (Genetic Algorithm for tuning of Integer controller) controller. AGC with load following is treated as an ancillary service that is essential for maintaining the electrical system reliability at an adequate level recent years, major changes have been introduced into the structure of electric power utilities all around the world.[11]

In this paper, an electrical energy management system, that implements an overall electricity consumption prediction model, was proposed. This model was established using the Fuzzy Logic method. Several individual houses were instrumented to highlight the importance of the prediction model. Finally, the system proposed here provides safety guarantees, and particularly during AC-line disconnection.[12]

Green energy targets for coming decades advocate high penetration of wind energy in main energy matrix, which pose incendiary threat to stability and reliability of modern electric grid if their integration aspects are not assessed beforehand. Real-time balancing of demand and supply or

Automatic generation control is a challenging task in modern electric grid when penetrated with unpredictable and variable wind power. [13]
In this study, fuzzy logic control approach is employed for load frequency control of an isolated system as well as on an inter-connected power system with non-reheat turbine system. The proposed fuzzy controller is reported as with better performance in comparison to PID controllers reported in literature. This mismatch has to be corrected by load frequency control (LFC), which is defined as the regulation of power output of generators within a tolerable limit.[14]
In this paper, the various optimization techniques for the Automatic Generation Control are introduced. From above discussion, it is clear that all techniques are having its distinct benefits like GA is a simple technique, suitable for less dimension problems. BF has global search ability. ANN is based on adaptive learning with no need of programming. Conventional controller is simple for implementation but takes more time and gives large frequency deviation.[15]
This paper addresses the issues in vertical handover and mobility management by proposing an intellectual algorithm to overcome these issues. This work increases the ability to continue accessing the ongoing services even when the node is handover to different network functionality. A seamless handover with low handover delay and packet loss is obtained by incorporating fuzzy based decision algorithm.[16]
A new hybrid Grey Wolf Optimization and Pattern Search (hGWO-PS) approach has been proposed to optimize the parameters of parallel Two Degree of Freedom of ProportionalIntegral-Derivative (2DOF-PID) controller for controlling the load frequency (LFC) in Automatic Generation Control (AGC) of two area interconnected power system of non-reheat thermal power plants. MATLAB/SIMULINK environment is used to simulate the results. The simulation results obtained by proposed technique (hGWO-PS) have also been compared with the results obtained by PSO optimized fuzzy PI controller and hybrid PSO-PS optimized fuzzy PI controller.[17]
This paper investigates the performance of the PI and PSO-PI controllers of a deregulated market structure for different transactions and contract violation. The concept of DISCO participation matrix (DPM) is implemented. A comparison of both the controllers shows that PSO tuned PI controller gives better results than the PI controller, namely reduced settling time, lesser overshoot and undershoot for all the cases under study. Performance characteristics in terms of the performance index Integral Square Error reveals that the designed PSO tuned PI controller is a promising control scheme for the solution of LFC problem and therefore it can be used to generate good quality and reliable electric power in the deregulated power systems.[18]

III. METHODOLOGY

System Block Diagram

In this block diagram we can see here is four power plants these are generates electrical energy. And here left sided power plats are power plant 1 and power plant 2. And right sided power plants are power plant 3 and power plant 4. Left sided power plants and right sided power plants are stable at short distance and connected together with dual converter. Power plant 1 is connected to step up transformer with bus B1 and power plant 2 is connected to step up transfrotmer with bus B2 these step up transformer is used for boost voltage of these power plants. Power plant 1 and power plant 2 powers is mixed together after bus B5 then this power go to bus B6 then go to bus b7. Then here is 20 MW load is connected that consume this power. Three phase fault detector is connected with Bus B7 that indicates when any fault is detected. Then this power goes to bus B8 then goes to bus B9. Bus B9 is connected with dual converter. Same work is done at the right hand side 1st plant 3 and plant 4 voltage is boost then mixed up at bus B12 then go to bus B10 via bus b11 and load is connected with bus B10. Dual converter is used for pass power from left power plants to right side. And right power plants to left side. If load at left side is high and left sided power plants not fulfill of power requirement of load then dual converter pass power from right side to left side. And if right side load is increases and right sided power plants are not full fill requirement of power then duel converter pass power from left side to right side.

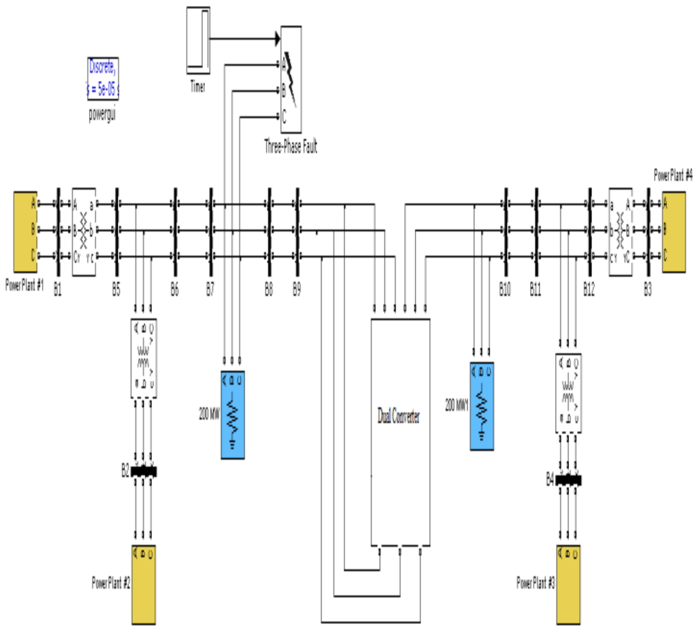

Fig: 3.1 System Block Diagram

PWM Invertor

PWM or Pulse width Modulation is used to keep the output voltage of the inverter at the rated voltage(110V AC / 220V AC) (depending on the country) irrespective of the output load.In a conventional inverter the output voltage changes according to the changes in the load.To nullify effect caused by the changing loads,the PWM inverter correct the output voltage according to the value of the load connected at the output.This is accomplished by changing the width of the switching frequency generated by the oscillator section. The AC voltage at the output depend on the width of the switching pulse.The process is achieved by feed backing a part of the inverter output to the PWM controller section (PWM controller IC).Based on this feedback voltage the PWM controller will make necessary corrections in the pulse width of the switching pulse generated at oscillator section.This change in the pulse width of the switching pulse will cancel the changes in the output voltage and the inverter output will stay constant irrespective of the load variations.

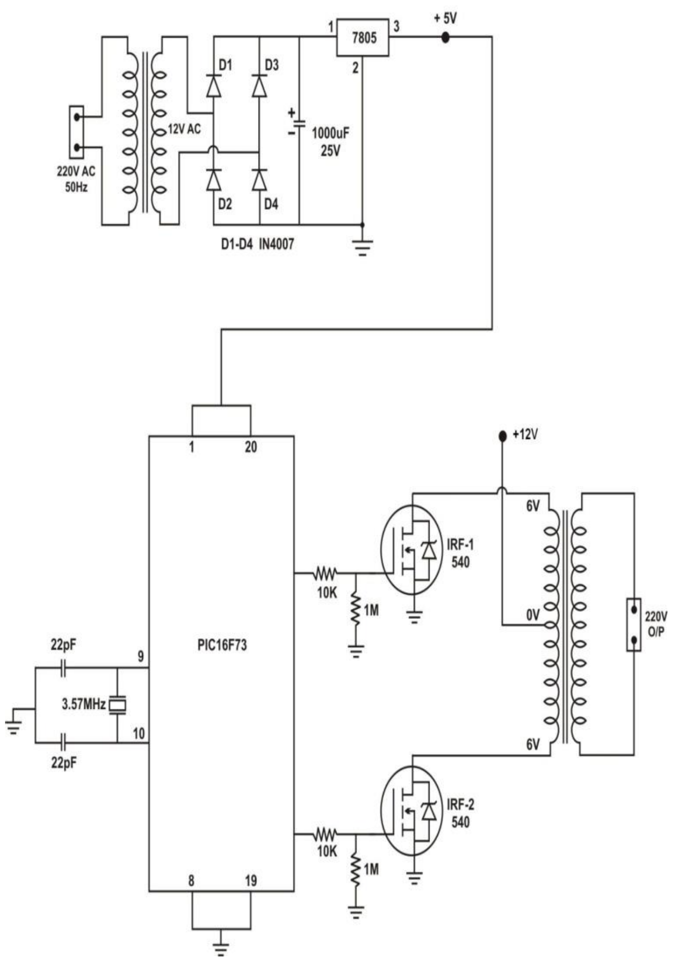

Fig: 3.2 Circuit Diagram of PWM Inverter

Dual H Bridge Flow Chart

In this flow chart we can see 1st main code is start then f0 to f3 of port B is equal to zero. Then after delay of 5 milli second f0 and f2 of port B is equal to 1 and f1 and f3 of port B is equal to zero. Then after delay of 5 milli second f0, f1, f2, f3 of port B is equal to zero. Then after delay of 5 milli second f0 and f2 of port B is zero and f1, f3 of port B is equal to 1. Then algorithm repeats.

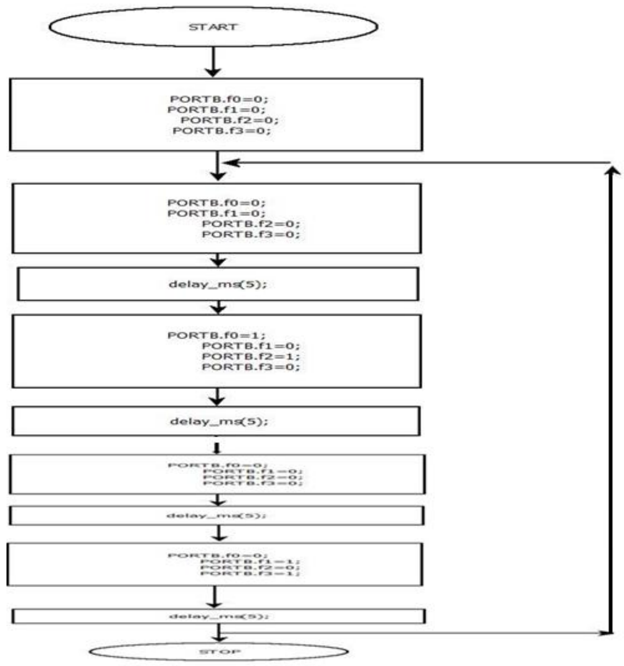

Fig: 3.3 H Bridge Flow Chart

Power Station Switching Protocol

In this table which is given below we can see when we give command on serial port then different power is on and off. When we give command ‘1’ then super thermal power is on. When we give command ‘2’ then super thermal power is off. When we give command ‘3’ then wind power is on. When we give command ‘4’ then wind power is off. When we give command ‘5’ then nuclear power is on. When we give command ‘6’ then nuclear power is off. When we give command ‘7’ then solar power is on and when we give command ‘8’ then solar power is off.

S.No.	Command	Action
1.	‘1’	Super Thermal Power On
2.	‘2’	Super Thermal Power Off
3.	‘3’	Wind Power On
4.	‘4’	Wind Power Off
5.	‘5’	Nuclear Power On
6.	‘6’	Nuclear Power Off
7.	‘7’	Solar Power On
8.	‘8’	Solar Power Off

IV. RESULT

In this window we can see how we run the main code by right click on the code option then click on Run.

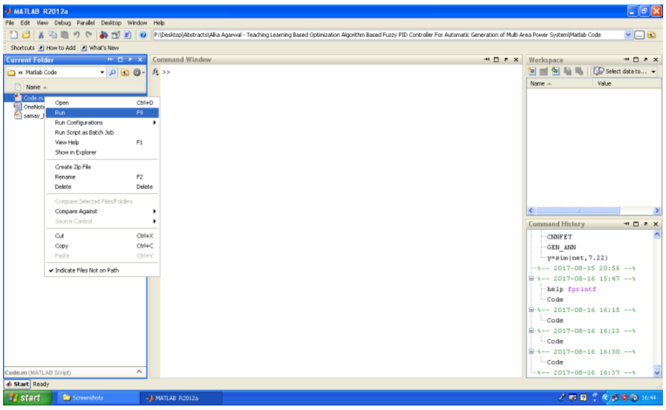

Fig 4.1 Run Main Code

In this window we can see after the click on the run button a loading window will be open.

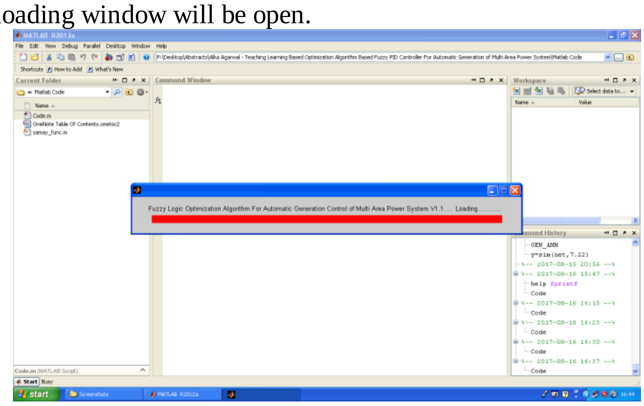

Fig 4.2 loading window

In this window we can see different voltage and current from the different power plants. When only solar power is on. When solar power, wind power and thermal power is on and nuclear power is off.

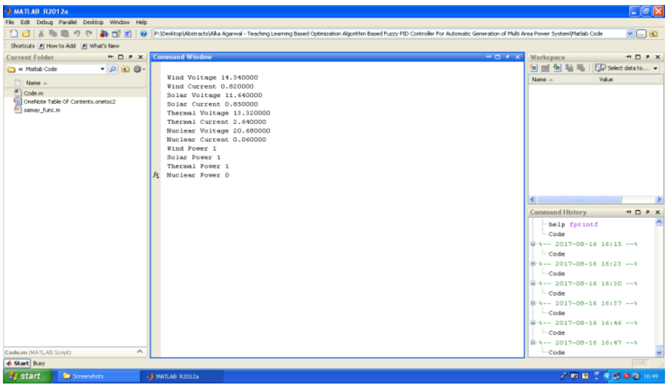

Fig 4.3 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants.When solar power, wind power and thermal power is on and nuclear power is off. When wind power , solar power, thermal power and nuclear power is on.

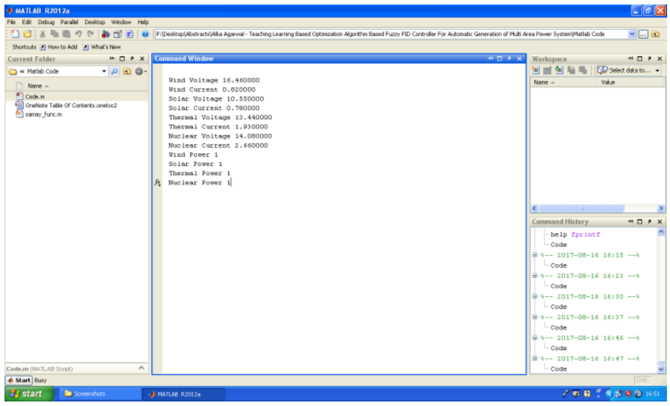

Fig 4.4 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants. When wind power, solar power, and thermal power is on and nuclear power is off.

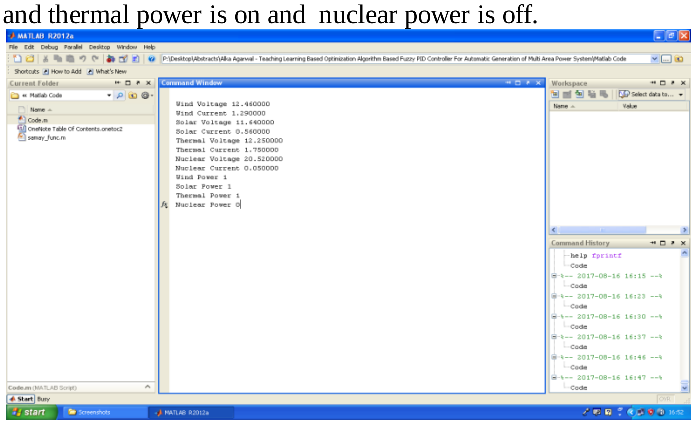

Fig 4.5 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants. When wind power power, wind power and nuclear power is on and thermal power is off.

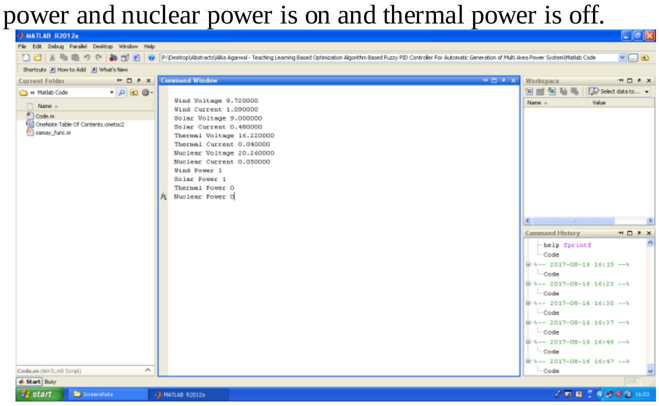

Fig 4.6 Voltage and current values from different power plant

S.No	Wind power	Solar Power	Thermal Power	Nuclear Power
1.	0.6408	5.1944	0.5259	0.6699
2.	12.8644	6.8876	0.3086	0.8836
3.	11.75	9.894	35.16	1.2408
4.	13.4972	8.229	25.9392	37.4528
5.	16.0734	9.3184	21.4375	1.0025
6.	10.5948	4.32	0.6488	1.013

Table: 4.1 Instantaneous powers of various power generations

S.NO	Wind Power	Solar Power	Thermal Power	Nuclear Power
1.	Off	On	Off	Off
2.	On	On	Off	Off
3.	On	On	On	Off
4.	On	On	On	On
5.	On	On	On	Off
6.	On	On	Off	Off

Table: 4.2 Switching Of Various Power Stations According To Load

In this image we can see waveform of PWM Inverter. Frequency of this waveform is 50 Hz, peak voltage is 5 volt and on duty cycle is 25 % and off duty cycle is 75%.

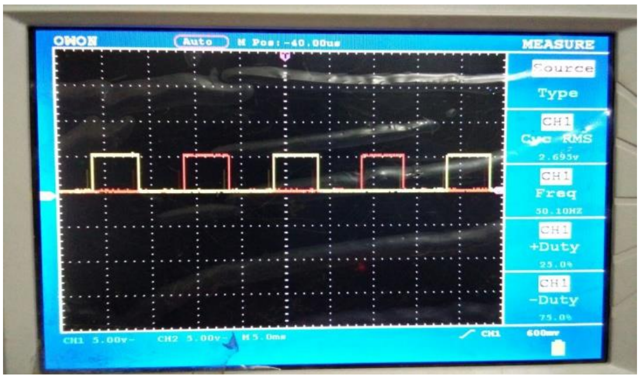

Fig: 4.7 PWM Inverter Waveform

V. CONCLUSIONS

The premise of this research is to optimize the cost of generation in multi area varied source power generation systems feeding combined load. As described above the system implements multiple (up to H) power generation setups by employing PWM inverters. More the over power generation setup connect to a load feeding bus or local AC bus. Also demonstrated is power sharing between various AC Buses (Local Buses) using dual converter.

The demonstration hardware setup is employs three 8 bit microcontroller from microchip for PWM generation, dual converter pulse generation & main controller acting as a slave serial unit to individually form on/off specific power generation setup according to the serial command. Successful implementation of embedded 'C' programming is demonstrated by PWM inverters & dual converter function & adherence of hardware to the predefined communication control process. Fuzzy logic controller for the proposed system has been developed in Matlab & is interfaced to the hardware over RS232 port using data equation toolbox methods. As demonstrate by the results the fuzzy controller automatically turns on or off requires power generation setups according to the load condition with prioritization of renewable energy & optimization of operational cost.

VI. FUTURE SCOPE

The author has proposed and demonstrates a multi area power generation algorithm with primary priority to renewable energy sources & also focused on cost optimization of generation station/sources. As the technology is rapidly evolving & energy crisis day by day there is continual demand in enhancements of systems cataing to multi area power generation especially micro power generation using renewable energy sores. A lot of enhancements can be introduced in the demonstrated work but the primilarily soughtones include inclusion of high speed data communication gateway over plcc & local RF repeaters to enable real time information & having between generation stations GSS, load despotch etc. to optimize generation reduce probability of faults & trips. Another important enhancement would be to include PWM control of dual converter to enable power flow quantity that control & prioritization to important load centers.

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