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Fuzzy Logic Energy Management Controller for Autonomous Wind Power Generation System

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ABSTRACT

This paper presents viability study of renewable wind power system for off-grid industries. Rapid depletion of fossil fuel resources necessitated research on alternative energy sources. A wind, solar or integrated renewable source system is a reliable alternative energy source because it uses natural source to generate electric supply to the load. In this paper Wind-Battery-Diesel hybrid power system is introduced for telecommunication tower applications. Fuzzy Logic based Energy Management Controller is proposed to monitor the input power and load demand continuously and to control whole system effectively. Fuzzy Logic Maximum Power Point Tracking is introduced for wind power system to provide a constant voltage with the help of DC-DC Single Ended Primary–Inductance Converter. Main objective of this paper is to supply uninterruptible power for telecommunication tower equipments from standalone wind system with suitable design of energy storage unit and a backup power system. The whole system is analyzed using MATLAB / Simulink

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INTRODUCTION

Economy growth of the country depends on the industrial growth where-in industrial growth depends on the electricity. The industry can run without any hurdles only when there is sufficient supply of electricity. As the industry grows the need for electricity also rises, which can be generated by proper utilizing natural resources. The country's economy grows with the sufficient supply of electricity generated by our own. Renewable energy is the energy which comes from unlimited natural resources such as water, sunlight, wind, tides and geothermal heat etc., Climate changes with day by day increasing hike on oil prices, shortage of coal and increasing government support, most of the developing countries are shown interest to promote renewable energy. Renewable energy is an alternative to fossil fuels and was commonly called alternative energy in the 1970s and 1980s. Wind power is growing at the rate of 21 % annually with worldwide installed capacity of 282.4 GW in 2012 is shown in Fig.1. However, all renewable energy sources have drawbacks. Wind and solar sources is dependent on unpredictable factors such as weather and climatic conditions. Due to both sources' complementary nature, some of these problems can be overcome by the weakness of one with the strengths of the other. In this paper wind power system is integrated with battery-diesel generator generally called as Integrated Power System (IPS), other than this combination so many hybrid systems are implemented with different renewable source combinations (Rabesh AbbaESSi, *et al*., 2012) for different applications (Joanne Hui, *et al*.,2016). Integrated energy system have proven to be advantageous for decreasing the depletion rate of fossil fuels, as well as supplying energy to remote rural areas, without harming the environment. In this paper wind power system is integrated with battery-diesel generator with dump load, generally called as Integrated Power Systems. Many Hybrid systems with renewable sources are implemented for different applications.

India is the leading country in Asia and one of the leading country in the world in generating electric power through renewable energy sources. In wind power generation India retained its position in top five in the world ranking. India will install 30 GW of renewable power by 2017. Tamil Nadu is one of the wind power hubs of India and South Asia. Tamil Nadu generates 40 % of India's wind power (7300 MW). An average wind speed

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during the peak wind season (May-September) is 10kmph is shown in Fig.1 and an average power generation is 2,500 MW, the generation goes as high as 4000MW.Unreliable electrical grid supply is one of the biggest challenges faced by the rapidly growing telecommunication tower industry in India. Today, an average, 70 percent of the approximately 400,000 mobile towers in India faces electrical grid outages in excess of 8 hours a day. Telecom tower operates currently use diesel generators, batteries etc

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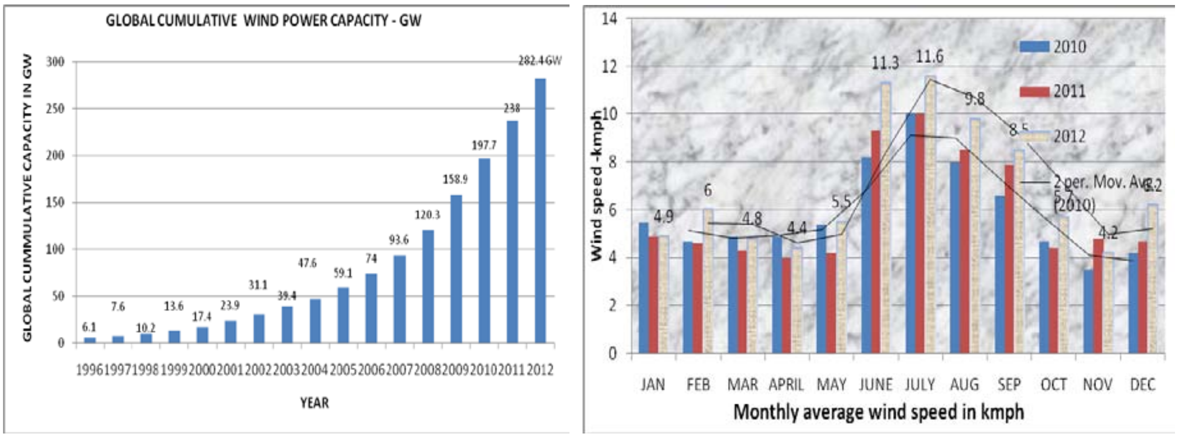

Fig. 1: Global Cumulative Wind Power Generation by 2012.&Avrage wind speed in kmphYr 2010-12

The Indian telecommunications industry is one of the fastest growing in the world and India is projected to become the second largest telecom market It is estimated that total number of telecom towers would research 1,000,000 by 2017.The telecom tower industry in India is estimated to consume over 2.5 billion litres of diesel annually making it the second largest consumer of diesel in the country. According to the Telecom Regulatory Authority of India (TRAI-www.trai.gov.in), the number of telecom subscribers in the country increased to 562.21 million in December 2009, an increase of 3.5 % from 543.20 million in November 2009 With this the overall teledensity (telephones per 100 people) has touched 47.89. According to Business Monitor International, India is currently adding 8-10 million mobile subscribers every month. It is estimated that by mid 2012, more than half the country's population will own a mobile phone. This would translate into 700 million mobile subscribers, accounting for a tele-density of around 60 per cent by 2012. Presently 40% power requirements are met by grid electricity and 60% by diesel generators which consume about 2 billion liters of diesel per year. The diesel generators are of 10-15 KVA capacity and consume about 10 liters of diesel per hour and produce 2.63 kg of CO_2 per liter. The total consumption is 2 billion liters of diesel and 5.3 million liters of CO_2 is produced. For every KWH of grid electricity consumed 0.84 Kg of CO_2 is emitted. Total CO_2 emission is around 5 million tones of CO_2 due to diesel consumption and around 8 million tons due to power grid per annum.List of top 10 countries by 2011. India is in fourth place in the list of top 10 countries by 2011 CO_2 emissions, the move from diesel to wind and other alternate renewable sources of energy will result in a reduction of 5 million tons of CO_2 emissions per year. To reduce the fuel consumption and pollution by diesel engine, natural resource available in that area is utilized by individually or Integrated Power System(IPS) mode to provide essential power to remote and off-grid locations. Many researchers have been done early by many engineers to improve the reliability of IPS). In this paper Fuzzy Logic Energy Management Controller (FLEMC) is proposed to provide the maximum reliability in IPS for telecom applications. Since telecom load needs uninterrupted power explained by (Stephan S.Smith and M.Tariq Iqbal 2008). Solar-diesel-integrated power system for telecommunication applications is explained in (k.Sekar and V.Duraisamy, 2013). The usage of diesel engine is minimized and continuous power supply is provided by FLEMC based IPS.

Autonomous Wind Power System (AWPS):

Autonomous operation is the ability of a system to run the load on site-generated or stored power. With the reduced power consumption of modern telecommunications equipment (Juergen Biela, *et al*., 2009), wind power system has become an economically and technically attractive alternative to conventional energy sources. Wind and solar power can be used in microwave repeaters, cellular base stations, Radio station (Sangsefidi.Y,S,*et al*.,2012), telephone exchanges and satellite earth stations etc. Many existing sites that operate 24 x7 on diesel fuel can transition to wind system to reduce the burden of costly fuel and maintenance of diesel run generators. The main advantages are that power can be generated with very short span, it has free source, and so minimal maintenance cost, it is easy to manage and is more reliable than diesel generator powered systems. In this paper wind power is the prime source, the power generated from the wind sources are connected with bus through converter, MPPT unit and source selector switch. There are three types of integration available, they are DC coupled, AC coupled and integrated coupled. In an AC coupled, sources are connected to the AC grid where synchronization is required. Synchronization makes integration little bit complex. In DC coupled, sources are connected to the DC grid where synchronization is not required (Sangsefidi.Y,S, *et al*., 2012).

The proposed Autonomous wind Power System (AWPS) is illustrated in Fig. 3. All DC source avail is controlled by DC- DC converters, which makes DC suitable power for telecom tower equipments. For DC-DC conversion SEPIC converter is proposed because of SEPIC converter acts as a boost or buck mode to increase / decrease or equal the required DC voltage and diesel source SEPIC converter acts as a buck converter to reduce the required DC 48 V. Battery bank is charged through charge controller with SEPIC boost converter with DC 54 V to get steady charging. Battery bank discharging is controlled by selector switch. Dump load is connected to the grid to act as a load when the energy production is excess than load and state of battery is fully charged. In this proposed system Dump load is auxiliary battery bank to utilize the sources effectively. All sources and dump load are connected to the grid through individual selector switch. Initially Telecom tower load is supplied with energy storage system, discharging mode selector switch is closed and when the prime source is ready to produce supply (velocity > 8m/s) then wind source selector switch is closed and remaining switches are turn off. All source selector switches are controlled by Fuzzy Logic Energy Management Controller .FLEMC plays a major role in selecting source to grid.

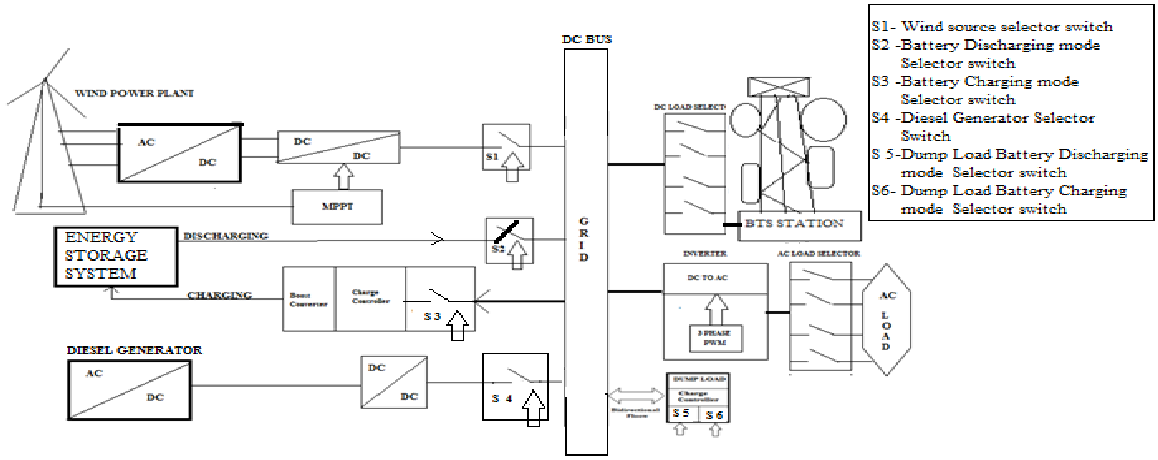

Fig. 2: Block diagram of Autonomous Wind-Battery -Diesel Integrated power system

The small-medium scale wind industry has developed in many aspects, and today's product designs are improved and deliver energy more efficiently than previous years. A Maximum Power Point Tracking (MPPT) is a high efficiency DC-DC converter that produces an optimal electrical load from a source and produces a voltage suitable for the load. MPPT utilizes some type of control circuit and logic or rules to surch maximum point and thus allow the converter circuit to extract the maximum power (Rishabu Dev Shukla, Dr.R.K.Tripathi, 2012).Wind power is generated using the proper turbine and generator. The wind turbine captures the winds kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator When considering a wind system, a good analysis of wind distribution and velocity is required. The turbine is mounted on a tall tower to enhance the energy capture. Wind turbines are classified into two general types: Horizontal axis and Vertical axis. Since vertical axis wind mill do not take the advantage of the higher wind speeds at higher elevations above the ground, in this paper horizontal axis wind turbine is proposed.

In this paper Permanent Magnet Synchronous Generator (PMSG) (Melício.R, *et al*., 2010) acts as an alternator to produce electrical power, other than PMSG, Doubly Excited Permanent Magnet Brushless Machine(Chunhua, *et al*., 2010), and Self Excited Induction Generator (SEIG) (Marcelo Godoy Simoes, *et al*., 1997) etc. are used in wind system. Permanent Magnet Synchronous Generator is preferred for wind power plant because of its high efficiency (Bharanikumar.R, *et al*., 2010) & (Vlad.C, *et al*., 2008) and power coefficient, Secure and stable operation, no need of slip rings and power factor correction condensers. However, estimating wind velocity, wind speed and quality vary from site to site and so performance calculation is complex. PMSG produce AC power and is converted to DC by diode rectifier then this DC is given to DC-DC SEPIC converter and fixed DC output is connected to DC Bus through selector switch S1. Initially Telecom tower load is supplied with energy storage system, discharging mode selector switch is closed and when the prime source is ready to produce supply (velocity > 8m/s) then wind source selector switch is closed and remaining switches are turn off .Suppose if wind velocity is going down then the load is shared with energy storage system is shown in Fig.3.a,b respectively

The amount of power produced by a wind turbine is expressed as shown:

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$P_T = 0.5 C_p \rho A V^3$ (1)

Where ρ is the air density, A is the cross sectional area of the turbine, V is the wind velocity

The co efficient of power (C_p) is a value dependent on the ratio between the turbine rotor's angular velocity (w_T), radius of the blade (R) and the wind speed (V). This ratio is known as the Tip speed ratio (TSR), is given by:

$TSR = w_{T.} R/V$ (2)

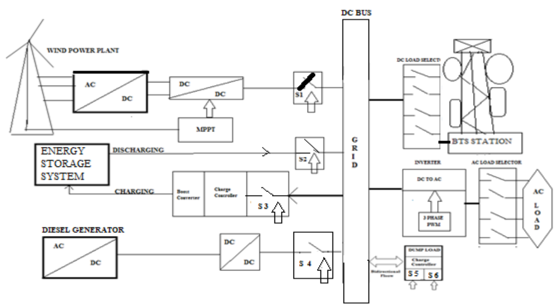

Fig. 3: a. Wind- alone supplies load

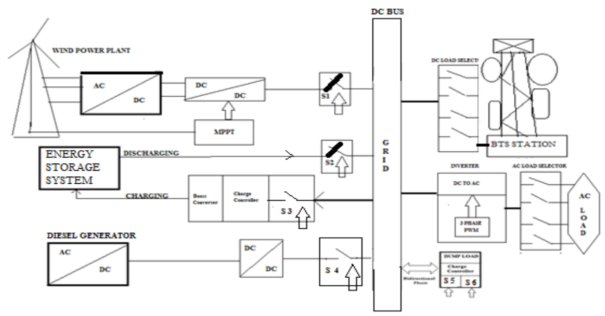

Fig. 3: b. Wind + Battery bank supplies load

From the relationship between TSR and C_p, it is possible to devise a control strategy that ensures that the wind turbine operates around or at the peak point of the curve. Such strategies are commonly referred to as Maximum Power Point Tracking (MPPT) techniques explained in (Marcelo Godoy Simoes *et al.*, 1997) & (Eftichios Koutroulis and Kostas Kalaitzakis, 2005). Fuzzy logic starts with and builds on a set of user-supplied human language rules.

Power Tracking Using Power Electronic Device: MPP Technique:

There are many MPPT algorithm is utilized for wind system.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. Wind speed error 'E' and error change rate 'EC' are used as fuzzy input and the modulation index 'm' as fuzzy output.

The degree of truth of E is configured as 7 degrees, all defined as {VN,N, LN,Z, LP,P, VP}, and EC is configured as 3 degrees all defined as {N,Z,P} where VN,N, LN,Z, LP,P and VP represent very negative, negative, low negative, zero, low positive, positive and very positive respectively. The degree of truth of "m "are configured as 7 degrees, lies between {0,1}. In this paper Sugeno type of fuzzy is proposed with Min-Max method fuzzification and weighted average method of defuzzification.Surface view of the fuzzy to show the utilization of rules and surface view of FLC is shown in Fig 4.

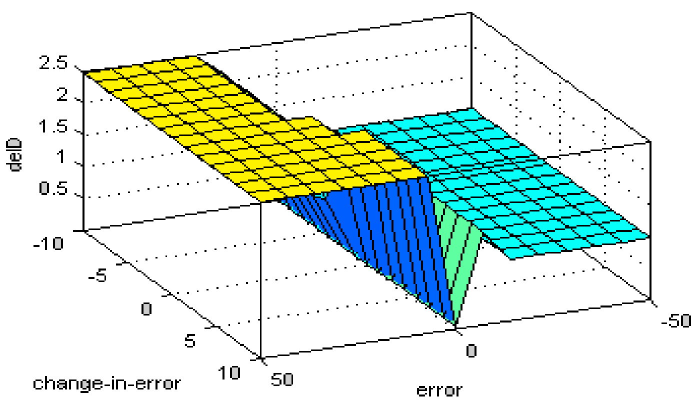

Fig. 4: Surface View of FLC

SEPIC DC-DC Converter:

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Power converters have developed continuously over the years and are utilized for various applications. There are many converters circuits some of them have become standard topologies. Power converters play a vital role in renewable based power systems to obtain constant voltage. The application of power electronics is expanding for a varity of new power equipment the role of power electronics for renewable energy is unpredictable. In applying power converters, the system is indispensable for improving performance of the whole system. When the input of the system is not constant, output of the system is also fluctuating. Telecom tower stations require a constant DC voltage, it is obtained by DC-DC converter. It may work in either buck (step down) mode or boost (step up) mode or no change mode. The single-ended primary-inductance converter (SEPIC) is a DC/DC-converter topology that provides a both buck / boost operation with positive regulated output analyzed in (Chakib Alaoui,Spectral, 2011) This type of converter is the optimum converter for renewable energy sources since source voltage fluctuates above and below the output voltage. Unlike cuk converter it produces output as in the same polarity of input. The buck / boost capabilities is possible in SEPIC in buck mode $V_{s1}<V_{IN.}$ in a boost converter, which generates a voltage (V_{S1}) that is higher than $V_{IN.}$ Assuming 100% efficiency, the duty cycle, D, for a SEPIC converter operating in DCM is given by switching losses of power device (MOSFET) in a SEPIC converter (Chakib Alaoui,Spectral, 2011) is given in (3)and is shown in Fig.5

$$P_{DSWITCHING} = (C_{RESS} \text{ x } V_{IN}^2 \text{ x } f_{SW} \text{ x } I_{LOAD}) / I_{GATE} \quad (3)$$

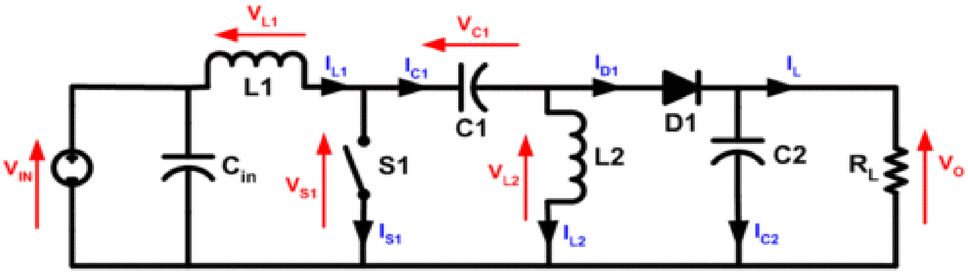


Fig. 5: SEPIC –DC-DC Converter

In the proposed project, less switching frequency is selected for switching the power device. It reduces the switching loss.

Back up and Standby Power System: Energy Storage System (ESS):

Due to the climate and seasonal weather changes, all renewable energy based power systems cannot produce power constantly, it required energy storage system. Wind energy plays a major role for a big share of renewable energy generation. There are many types of energy storage technologies, such as ultra capacitors, superconducting magnetic energy storage systems, pumped hydro, fuelcell, hydrogen storage system and batteries. Batteries have been a common type of energy storage for variety of applications and renewable energy power generation systems. Common types are Lithium-Ion, Lead –acid batteries etc., The role of storage system is to provide power or sharing of power, when any short fall occurs like low or non-availability conditions On the other hand when the generated power is greater than load demand the excess power is stored in this system lead-acid battery is proposed in this paper for energy storage. It has two modes of operation charging and discharging modes. When the current to the battery is positive, the battery is in the charging mode. When the current to the battery is negative, the battery is in the discharging mode. The storage methods for wind power systems are different. For small wind turbines small capacity storage is used like Lead-acid battery and for large wind turbines this is not feasible unless large scale compressed air or pumped hydro storage is used. In addition, for large scale wind system, the location of storage unit may cause the power loss in the system. Many researchers have been conducted on this topic. As the terminal voltage of the battery is given by

$$V_{bat}=V_1+I_{bat}R_1 \quad (4)$$

Here R_1 is the equivalent resistance of the battery. V_1 and R_1 both depend on the mode of battery operation and have different equations. Battery current; I_{bat} is positive when battery is in charge (ch) mode and negative when in discharge (dch) mode.

In charging mode, R_1 and V_1 are written as ,

$$R_1=R_{ch}=\left(0.758+\frac{0.139}{[1.06-SOC(t)]n_s}\right)\frac{1}{SOC_m} \quad (5)$$

$V_1=V_{ch}=(2+0.148SOC(t))n_s$ (6)

$P=P_s+P_w-P_b$ (7)

Equation (8) shows the total power of the IPS when the battery is charging. In discharging mode R1 and V1 are written as

$R_1=R_{dch}=.19+\frac{0.1037}{[SOC(t)-0.14]n_s})\frac{1}{SOC_m}$ (8)

$V_1=V_{dch}=(1.926+0.124SOC(t))n_s$ (9)

$P=P_s+P_w+P_b$ (10)

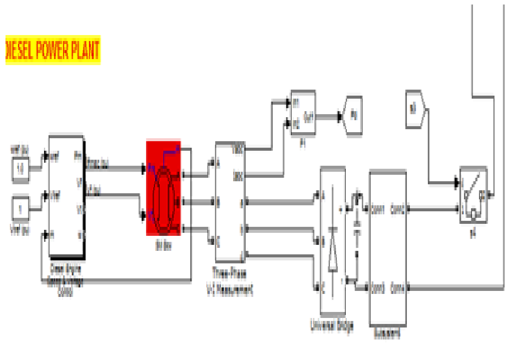
With the help of energy storage system it ensure the reliability and uninterrupted power to the load

Dump Load:

Dump load option is introduced in renewable power generation system especially wind power system. Many wind generation system installed air heater, resistive load act as a dump load. The function of dump load is to divert the excess power or when the system and energy storage system cannot accept the power being produced. In order to protect the system, the excess power is diverted and used in any useful work. In this paper I propose additional / Auxiliary Battery storage system (Rating is less than the main storage system or equal to load demand) is introduced and whenever the excess power is produced the first option is, it is stored in main storage system and if SOC of $P_{Bat} \geq 95$ % (this situation may happen occasionally), and this excess power is effectively stored in Auxiliary storage system (Act as Dump load). Here the dump load can have /perform two functions one is charging and discharging. Charging is taking place during excess power and or low load conditions only. This may cause more expense even though in this way we can protect the system from the excess power condition, increase the life of storage system and also minimize the diesel running time

Diesel Generator:

The standby power system is also required for renewable based power generation systems. In this paper diesel run generator is used as a standby power system. Output of DG is AC, it is converted to DC through diode rectifier (Joanne Hui, *et al*., 2010) and buck mode DC-DC SEPIC converter is used. It is switched ON by FLEMC only when all the sources are individually or in integrated conditions are not able to meet the load demand. In this condition controller activate the diesel source selector switch automatically. Now the load demand is met by DG and also battery charging continuously up to SOC of >95 % is as shown in Fig.6.b.Simulation model of DG unit is shown in Fig 6.a. This process is withdrawn when the main source is ready to supply to the load



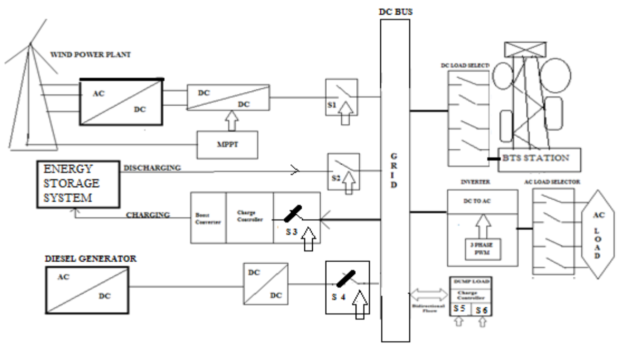


Fig. 6: a. Simulation model of DG **Fig. 6:** b. Hybrid model – DG + Battery charging

Fuzzy Logic Energy Management Controller (FLEMC):

The Fuzzy controller is implemented to improve performance of the overall system. Fuzzy system gives quick response than other controller. Based on the simplicity the fuzzy controller is suitable for any applications, such as Medical instrumentation, AC &DC motor speed control. It can perform individually or combined with PI (N.P. Ananthamoorthy, *et al*., 2013), PID controller. In this paper Fuzzy Logic Energy Management Controller (FLEMC) monitor the status of stand-alone system with all aspects, load, SOC of the battery and Dump load battery. Many stand alone energy management controllers have been developed for renewable

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system .FLEMC receives all sources existing power and load power. Depending on the load and available power generated by source, it selects individual source or combination of sources supply to the grid. It continuously monitors the SOC of battery and activates the charge controller when the battery does not supply the load and SOC is less than SOCm. Battery and dump load battery discharging is limited to SOC minimum of 20%. Always battery is in the state to supply load. When the load goes beyond the minimum load, FLEMC controls the sources and battery depends on load demand power availability. All output has 2 triangular membership functions is shown in fig.7, such as ON and OFF. Maximum possible combination of sources under various loads is formed as rules, 21 rules are proposed in this paper are shown in Fig.8a.

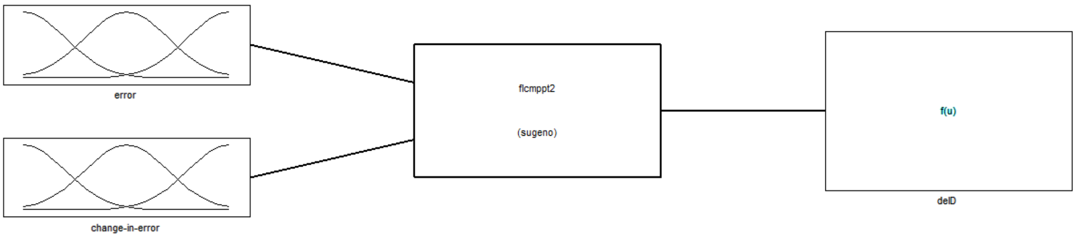
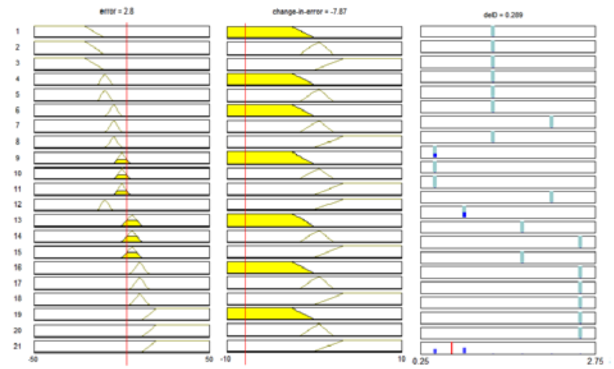


Fig. 7: Membership functions of Fuzzy Inputs

In this paper the proposed FLC based Energy Management Controller handles the non conventional energy sources effectively and extends the life time of Battery bank. When the load is low or at initial stages the battery bank supplies load. FLEMC produces signal and actuate discharging controller of the battery bank. The charging controller of battery bank is activated depends on the load demand, available resources and battery SOC. In case of high wind speed >22 m/s wind generator is turned off. In this paper Mamdani type of fuzzy is proposed with Min-Max method of fuzzification and centroid method of defuzzification.It has 4 inputs named as Pl, Pw, Pb and Pdb. It has 6 outputs such as S_1, S_2, S_3, S_4, S_5 and S_6 is shown in fig 8.b, .All input has 4 triangular membership functions such as Very Low, Low, Medium and High {VL, L, M and H}.



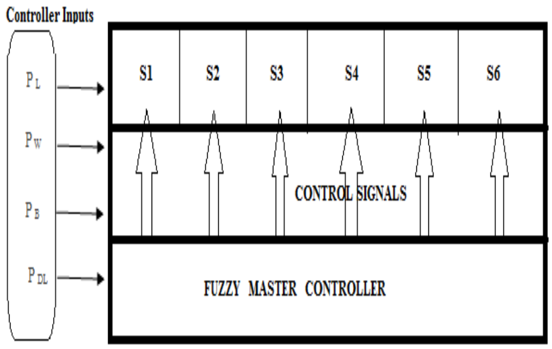


Fig. 8: a. Membership functions of output variable **Fig. 8:** b.Block diagram of LEMC

RESULTS AND DISCUSSION

Simulation model of IPS with energy management controller is developed using MATLAB/ SIMULINK R2011b. Proposed model rating of the HPS system is wind power plant is 1.5 KW, Battery Bank is 2.5 KW, Diesel run generator is 3 KW, DC Load is 1 KW,48 V and AC Load is 0.5 KW,440 V, 50 Hz, 3 phase. Since telecom tower equipments works in -48V DC (Stephan S.Smith and M.Tariq Iqbal, 2008) the proposed system is designed with the 48V DC bus. The positive grounded or negative voltage on the line was found to be a superior to positive voltage in preventing electro-chemical reactions from copper cables and also protects against sulphation on battery terminals IT leading cause of early battery failure. The - 48 V is given to the different equipments placed with BTS tower. The negative supply system will give better result and minimize the filter circuit .Three phase AC is obtained through DC to AC inverter which is used for other devices like light loads, cooling fan used in telecom station. In case of AC load, the 3 phase IGBT based Hex bridge inverter is connected from DC bus. Inverter is controlled by pulse width modulation technique. Output of inverter is filtered by LC filter and pure sine wave is given to the AC load. Tamil Nadu is one of the wind power hubs of India and South Asia. .Tamil Nadu generates 40 % of India’s total wind power (7300 MW). An average power generation, during the peak wind season (May-September) is an average of 2,500 MW, the generation goes as high as 4000MW. When the Telecommunication BTS equipments are equipped with Wind power system, tower equipments receive almost 150-200 days with full 24 Hrs with renewable source only. It reduces the running time of diesel generator, fuel consumption and also CO2 emission. Energy Management system function and Simulation results of different cases are shown in Fig: 8- Fig 12 respectively.

Case-1:

The Fig 8 shows the status of single source supplies load. Main source is sufficient to run the load. The selector switchs S1& S_3 are switched ON and remaining switches are in OFF position. Charging of battery is also takes place if SOC < 20%

$$Pw > P_L \ \& \ Pw = P_L + P_{B\,CHAR} \qquad \text{If SOC} < 20\,\% < 95\% \qquad (11)$$

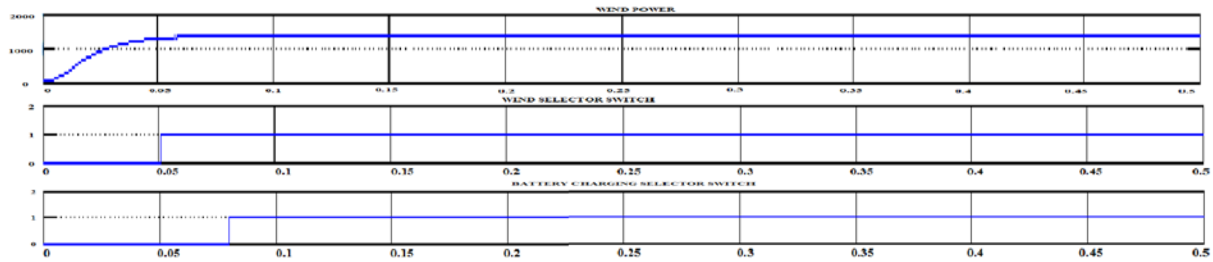


Fig. 8: Simulation result of the AWPS when Prime source alone supplies load

Case-2:

The Fig 9 shows the status of battery bank supplies load. It is the state when no or low or insufficient input conditions. Under this condition battery bank discharging takes place switch S2 is activated and remaining switches are in OFF mode. SOC of battery is maintain at >95 %

$$Pw \neq P_L \ \& \ P_{B\,discharge} = P_L \qquad (12)$$

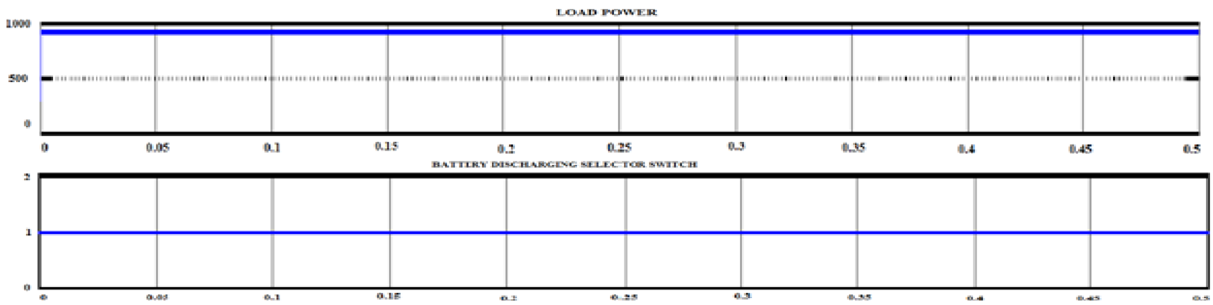


Fig. 9: Simulation result of the AWPS when Battery alone supplies load

Case-3:

The Fig 10 shows the status of main source integrated with battery bank supplies load. It is the state when wind is available but it's not sufficient to meet out load demand. Both wind-battery integrated modes will meet the load. S_1 & S_2 are switched ON and remaining switches are in OFF state.

$$Pw << \neq P_L \ \& \ P_w + P_{B\,discharge} = P_L \qquad (13)$$

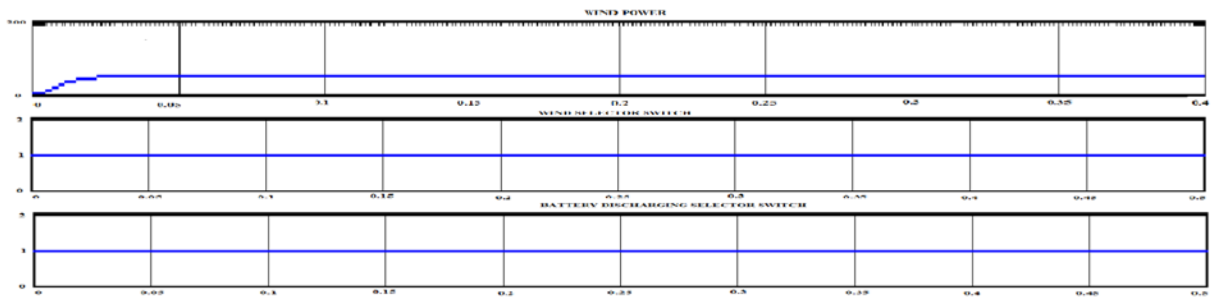


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Fig. 10: Simulation result of the AWPS when Wind power + battery bank supplies load

Case-4:

The Fig 11 shows the status of prime source shares power with diesel generator. In this case if soc of P_{bat} is less than 20 %, the charging also takes place. Switches S_4, S_1 & S_3 are switched ON and remaining switches are in OFF state. It is shown in equation (14)&(15).

$$Pw << \neq P_L \& P_w + P_{B<20\%SOC} << \neq P_L \text{ and } P_{DL\ discharge} << P_L \quad (14)$$

$$P_{DG} >= P_L \& P_{DG} = P_L + P_{B\ CHAR} \quad (15)$$

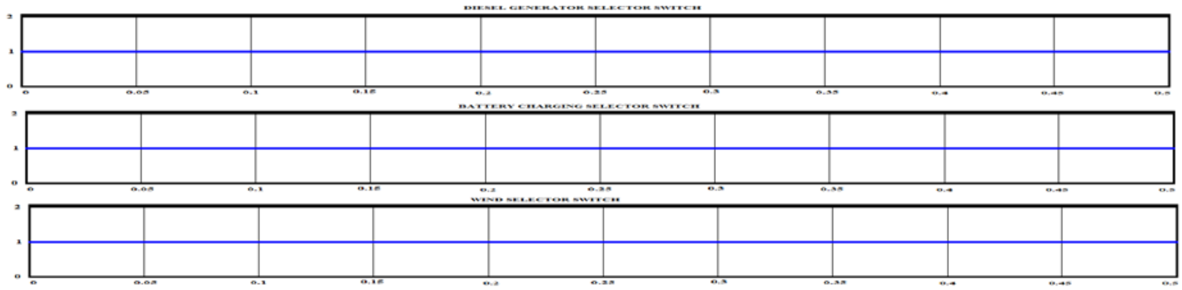

Fig. 11: Simulation result of the AWPS when Prime source shares with DG

Case-5:

The Fig 12 shows the status of prime source alone supplies load. In this case if soc of P_{bat} is less than 20 %, the battery charging takes place, it stopped when SOC > 95% at the same time if $P_{dumpbat}$ is less than 20 % then, dump load battery charging takes place upto >95%. Switches S_1& S_6 are ON and remaining switcher are in OFF state.

$$P_W >> P_L \ \& \text{ if } P_{Bat} \geq 95\ \% \text{ of SOC then } P_W = P_L + P_{dl\ Charging} \quad (16)$$

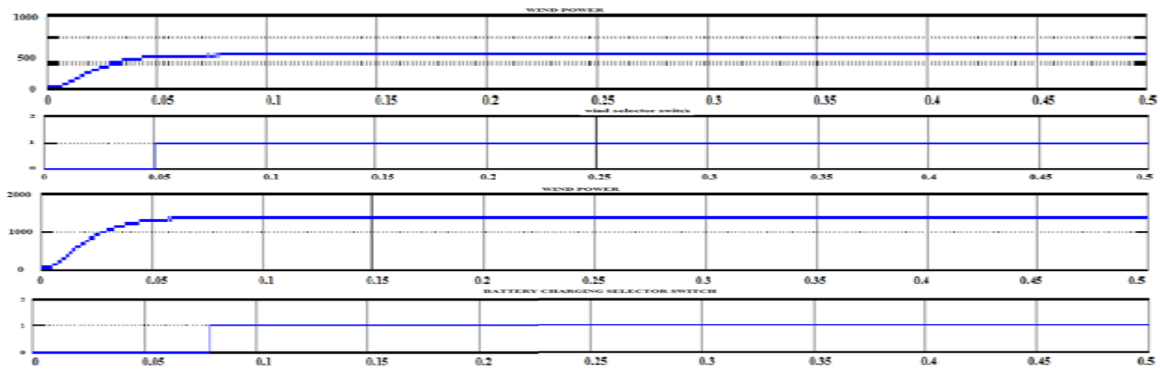

Fig. 12: Simulation result of AWPS when main source shares Power with dump load battery

Conclusion:

The Autonomous wind –battery-diesel integrated power system is simulated using MATLAB. Fuzzy Logic MPPT Control is applied in wind source which makes the system efficient. Autonomous power system supplies AC and DC load so it is suitable for all applications like villages, remote areas, and hill stations. A fuzzy Logic Energy Management Controller control proposed power system to provide uninterrupted power, minimizing usage of diesel, effective utilization of natural source and improves life time of battery. From the simulation results and various fuzzy rules conditions, integrated system supplies uninterrupted power to the load effectively throughout the year. This proposed system is optimally suitable for Telecommunication load in off grid areas, where constant voltage and continuous power is required. Instead of single renewable source with battery-diesel generator integrated power system, we can use two or more renewable sources (Solar- Wind - Fuel Cell etc.,) integrated with battery – diesel generator. By suitable modification of power control strategies presented in this paper, the same system with different ratings can be used power up any kind of loads.

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