

# Autonomous Wind-DG Microgrid with Back Propagation Algorithm Based Fuzzy Logic Strategy

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**Abstract**— This paper manages a wind-DG (Diesel Generator) hybrid setup of the microgrid utilizing a voltage source converter (VSC) as a voltage and frequency controller (VFC). The wind control created by permanent magnet brushless DC generator (PMBLDCG), and the most extreme power is caught by a maximum power point procedure (MPPT) utilizing a lift converter with an incremental conductance (INC) approach. This power is provided to the user's burdens and surplus power is put away into battery system (BS). BS is joined at DC connection of VSC which gives stack leveling during less or no wind conditions. With such blend of energy assets, a diminished rating, diesel motor driven squirrel confine enlistment generator (SCIG) encourages burdens and VSC at point of common coupling (PCC) underpins the system when the wind generation can't take care of out the load demand. Back spread encourage forward (BPFF) control calculation is utilized for VF control of VSC. This controller gives sounds disposal, stack leveling and reactive power compensation and furthermore directs the voltage at PCC. This microgrid is demonstrated in MATLAB Sim control apparatuses and reenactment results are created to confirm the proper working of both the converters and the generations system.

**Index Terms**—BPFF, Fuzzy Logic, MPPT, THD.

## I. INTRODUCTION

In the period of globalization and innovative progression, the way of life and expectations for everyday comforts have turned out to be particularly subject to electrical devices and machines, which give solace, accommodation and spare time. The electrical energy is for the most part delivered from conventional sources (fossil fills) which are restricted and in declining stage now. In addition, higher power generation cost with fossil powers is additionally sympathy toward scientists. The mechanical efforts are being made to meet energy prerequisites by most extreme use of non-routine environment well-

disposed energy sources, for example, sun oriented, wind, tidal, bio-gas and so forth.

The principle challenges with the renewable assets are their unusualness and variable nature. With these assets, limiting force supply varieties and keeping up power quality are the prime issues for scientists. In troublesome land territories where primary power grid is not available, the idea of building up a neighborhood microgrid in mix with routine fuel based generator sets and renewables can be emerged. A portion of the cross breed systems are without the battery stockpiling (BS) systems and some are accounted for with BS. The systems working without the BS need to derate during high wind rates and detachments, when the request is less also, generation is high. With BS, the over energy can be put away into it and is used during pinnacle stack hours.

Independent systems are accounted for with BS to give security to the microgrid during over power control generation and load leveling during low generation or pinnacle stack request. In this way, BS outline and size computation are essential for detached microgrid. Battery charging control is likewise announced in for ideal charging and solid operation of microgrid. Wind energy transformation system and DG set are one of such half breed blends, where the wind power is put away in BS and the over power is used to supply the load, while DG set gives AC energy to the load. This arrangement diminishes the fuel utilization and monetarily uses the customary energy assets.

In this paper, an independent microgrid is utilized that constitutes SCIG (Squirrel Cage Induction Generator) based DG (Diesel Generator) because of its minimal effort and less support and PMBLDCG (Permanent Magnet Brushless DC

Generator) as WECS (Wind Energy Conversion System), the reason being its straightforward development, high power thickness and swell less torque. It is associated with a 3-stage rectifier, a lift converter for MPPT. For most extreme power extraction, an incremental conductance approach is utilized, which gives agreeable outcomes during wind varieties and is financially savvy as it is a sensor-less approach. This wind power is used by the loads and at the same time it is put away in the battery bank during typical load request and can be used during pinnacle stack request. In this manner, the battery bank builds system unwavering quality. With such mix of energy assets, a diminished rating diesel generator is utilized as a part of microgrid. Single voltage source converter (VSC) connected between battery bank and PCC fills in as VF (Voltage and Frequency) controller. In this work, a BPF (Back Propagation Feed Forward) calculation is executed to determine control quality issues identified with the microgrid. This system is found in 1987 by Rumelhart and McClelland and it is effectively executed in different fields. It is a neural system managed learning based approach utilized for an aberrant current control of VSC.

**II. SYSTEM CONFIGURATION AND CONTROL**

A microgrid comprises of DE (Diesel Engine) driven SCIG and PMBLDCG based WECS as appeared in Fig.1. The diesel generator (DG) is sustaining 3-stage loads with VSC which controls voltage and frequency of the system as VFC. The PMBLDC generator changes over the twist energy to electrical AC control and actuates trapezoidal EMF and semi square streams, which produces swell free torque at generator end. This power is amended into DC utilizing a 3-stage diode-connect. Second stage is the DC-DC transformation which utilizes a lift converter and MPPT is acknowledged with INC calculation. An inductor makes the DC current smooth and steady and the diode chooses its heading of stream. This is appended at DC connection of VSC shunted with BS where a battery gives stack leveling during less or nil wind generation. The battery is charged when the wind power is accessible and is released for low winds and at high load request. DG system gives AC energy to the AC straight/nonlinear burdens. SCIG has no field windings for voltage development, in

this manner, outside reactive power is given by a delta associated capacitor bank. The created voltage and frequency are managed by VFC.

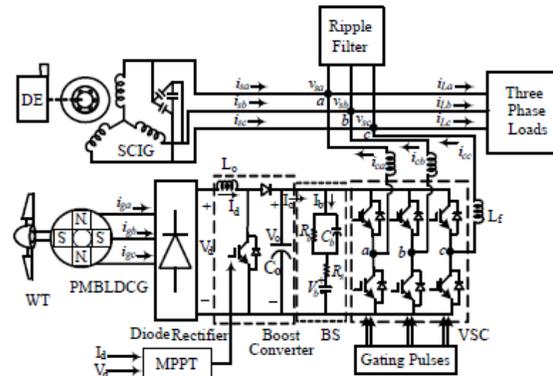


Fig.1: Schematic diagram of Wind-Diesel microgrid

**A. Back Propagation Feed Forward Network Controller**

BPF (Back Propagation Feed Forward) based control calculation manages voltage and frequency of the microgrid. In this plan, multi-layered encourage forward system is included an information layer, shrouded layer and aoutput layer. The info flag goes in encourage forward heading from an information layer towards aoutput layer on layer by layer premise. Regulated learning with back-propagation calculation is executed here which chips away at blunder redress learning standards to accomplish wanted outputs. Its portrayal is given here as indicated by Fig.2.

In-stage and quadrature layouts of PCC voltage are figured as,

The pinnacle terminal voltage  $V_t$  is characterized as,

$$V_t = \sqrt{\frac{2}{3}(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)} \tag{1}$$

where  $v_{sa}, v_{sb}, v_{sc}$  are phase voltages.

The in-phase unit templates are expressed as,

$$u_{pa} = \frac{v_{sa}}{V_t}, u_{pb} = \frac{v_{sb}}{V_t}, u_{pc} = \frac{v_{sc}}{V_t} \tag{2}$$

The quadrature unit templates are defined as,

$$u_{qa} = \frac{(u_{pc} - u_{pb})}{\sqrt{3}} \tag{3}$$

$$u_{qb} = \frac{(3u_{pa} + u_{pb} - u_{pc})}{2\sqrt{3}} \tag{4}$$

$$u_{qc} = \frac{(-3u_{pa} + u_{pb} - u_{pc})}{2\sqrt{3}} \tag{5}$$

Reference input streams are processed with synaptic weight estimations of load ebbs and flows, a dynamic and reactive power segments. Three-layers as an info, covered up and output layers are taken to understand the control. Input layer neurons in its first half segment as an accumulation work for dynamic and reactive power part of load current for "b" stage are communicated as,

$$I_{Lpb} = w + i_{La}u_{pa} + i_{Lb}u_{pb} + i_{Lc}u_{pc} \tag{6}$$

$$I_{Lqb} = w + i_{La}u_{qa} + i_{Lb}u_{qb} + i_{Lc}u_{qc} \tag{7}$$

where w is the underlying estimation of synaptic weight. Both the parts of stage 'an and c' ( $I_{Lpa}$ ,  $I_{Lpc}$ ,  $I_{Lqa}$  and  $I_{Lqc}$ ) are computed in the comparable way. These qualities are gone through second part as enactment capacity of information neurons, which are sigmoid capacities here. The output of info layer neurons for stage "b" are

$$\text{communicated as, } X_{pb} = \frac{1}{(1 + e^{-I_{Lpb}})} \tag{8}$$

$$X_{qb} = \frac{1}{(1 + e^{-I_{Lqb}})} \tag{9}$$

where w is the underlying estimation of synaptic weight. Both the parts of stage 'an and c' ( $I_{Lpa}$ ,  $I_{Lpc}$ ,  $I_{Lqa}$  and  $I_{Lqc}$ ) are computed in the comparable way. These qualities are gone through second part as enactment capacity of information neurons, which are sigmoid capacities here. The output of info layer neurons for stage "b" are communicated as,

$$I_{pbl} = w_1 + w_{pa}X_{pa} + w_{pb}X_{pb} + w_{pc}X_{pc} \tag{10}$$

$$I_{qbl} = w_1 + w_{qa}X_{qa} + w_{qb}X_{qb} + w_{qc}X_{qc} \tag{11}$$

Different conditions for  $I_{pal}$ ,  $I_{pcl}$ ,  $I_{qal}$  and  $I_{qcl}$  are likewise computed in comparative way. Here  $w_1$ ,  $w_{pa}$ ,  $w_{pb}$ ,  $w_{pc}$  are a few constants values between (0, 1) to introduce the weights. These qualities are overhauled by back engendering blunder

amendment run the show. Amended weights of stage "b" dynamic and reactive power segments of load streams  $w_{pb}$  and  $w_{qb}$  at  $r^{th}$  testing time are as,

$$w_{pb}(r) = w_{pb}(r) + \eta(w_{pb}(r) - w_{pbl}(r))w'_{pbl}X_{pb}(r) \tag{12}$$

$$w_{qb}(r) = w_{qb}(r) + \eta(w_{qb}(r) - w_{qbl}(r))w'_{qbl}X_{qb}(r) \tag{13}$$

Likewise, the upgraded values for stage "a" and "c"  $w_{pa}$ ,  $w_{pc}$ ,  $w_{qa}$  and  $w_{qc}$  are processed. These qualities are gone through actuation work i.e. sigmoid capacity here. The dynamic and reactive power part of load streams  $w_{pal}$ ,  $w_{pcl}$ ,  $w_{qal}$  and  $w_{qcl}$  are computed like that of stage

$$w_{pbl} = \frac{1}{(1 + e^{-I_{pbl}})} \tag{14}$$

$$w_{qbl} = \frac{1}{(1 + e^{-I_{qbl}})} \tag{15}$$

Amplitude of the generation of active and reactive power components of load currents is defined as,

$$w_{pr} = \frac{a \times (w_{pal} + w_{pbl} + w_{pcl})}{2} \tag{16}$$

$$w_{qr} = \frac{b \times (w_{qal} + w_{qbl} + w_{qcl})}{3} \tag{17}$$

DC part of the weighted segment is removed through LPF as these are standardized values between (0, 1). Along these lines to get genuine estimation of dynamic and reactive power segments of load streams they are scaled with an and b considers separately. Dynamic power segment of reference information current can be assessed by subtracting wind dynamic part,  $w_{pw}$  devoured from dynamic segment of load present as,

$$w_{pw} = \frac{P_o}{3V_t} \tag{18}$$

$$w_{pc} = w_{pr} - w_{pw} \tag{19}$$

The reactive part of reference info current is registered utilizing a PI controller. The AC transport voltage mistake  $V_e$  is communicated as,

$$V_e(r) = V_r(r) - V_t(r) \tag{20}$$

Weighted value of PI controller to regulate terminal voltage at  $r^{th}$  instant is calculated as,

$$w_{pr}(r) = w_p(r-1) + k_p(V_e(r) - V_e(r-1)) + k_i V_e(r) \tag{21}$$

where  $w_{qv}$  is a piece of reactive reference input current.  $k_{pv}$  and  $k_{iv}$  are corresponding and essential additions of PI controller.

The reference reactive current part is processed as,

$$W_{qs} = W_{qv} - W_{qt} \tag{22}$$

The fundamental reference active and reactive power components of the 3-phase input currents are calculated as,

$$i_{spsa}^* = W_{ps} U_{psa}, i_{spsb}^* = W_{ps} U_{psb}, i_{spsc}^* = W_{ps} U_{psc} \tag{23}$$

$$i_{sqsa}^* = W_{qs} U_{qsa}, i_{sqsb}^* = W_{qs} U_{qsb}, i_{sqsc}^* = W_{qs} U_{qsc} \tag{24}$$

$$i_{sa}^* = i_{spsa}^* + i_{sqsa}^*, i_{sb}^* = i_{spsb}^* + i_{sqsb}^*, i_{sc}^* = i_{spsc}^* + i_{sqsc}^* \tag{25}$$

These 3-phase reference input currents ( $i_{sa}^*$ ,  $i_{sb}^*$ ,  $i_{sc}^*$ ) and sensed input currents ( $i_{sa}$ ,  $i_{sb}$ ,  $i_{sc}$ ) are compared to generate PWM pulses for the switching of VSC.

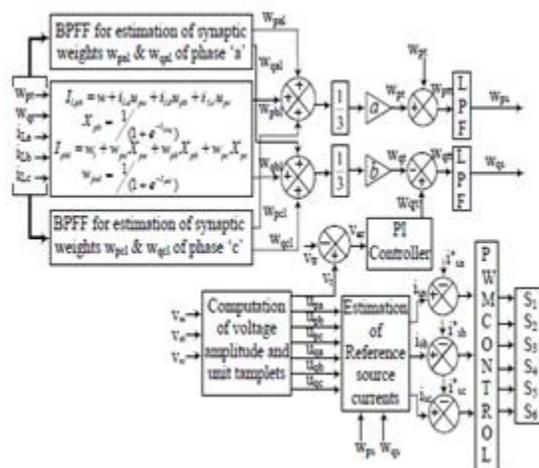


Fig. 2: Schematic diagram of BPFcontrol Technique

**B. Maximum Power Point Tracking (MPPT) Scheme.**

The obligation cycle of DC-DC help converter is computed straightforwardly as indicated by the MPPT. For MPPT, the subsidiary of output power and voltage of diode scaffold must be zero i.e. expansion of immediate conductance and incremental conductance,  $Z = (I_d/V_d + \Delta I_d/\Delta V_d)$  is zero. Because of progress in any particular parameter, if the point moves towards right hand side and Z gets to be distinctly negative, the obligation cycle increments to keep up the MPPT. On the off chance that the point moves towards left hand side and Z gets to be distinctly positive then the obligation cycle declines to keep up the MPPT.

**III. DESIGN OF WIND AND DIESEL HYBRID CONFIGURATION**

This microgrid comprises of a SCIG based DG set of rating 230 V, 50 Hz and 3.7 kW and a twist generator of limit 3.7 kW, 230 V, 50 Hz under three-stage adjusted nonlinear and direct loads.

**C. DC Bus Voltage and BS Selection**

The voltage at the DC link of the VSC is computed as,

$$V_{dc} = \frac{2\sqrt{2}}{\sqrt{3}m} V_L \tag{26}$$

where m is the adjustment list, if considered 1 and  $V_L$  (230V) is the line rms voltage.  $V_{dc}$  is gotten as 375.6 V which is viewed as 400V.

A Thevenin's model is utilized to depict BS, where ( $C_b$ ) capacitance and resistance ( $R_b$ ) are associated parallel alongside arrangement associated interior resistance ( $R_s$ ) and a perfect voltage wellspring of voltage 400V. Identical capacitance  $C_b$  is computed as [12],

$$C_b = \frac{(kW.h * 3600 * 1000)}{0.5(V_{ocmax}^2 - V_{ocmin}^2)} = 1125F \tag{27}$$

where  $V_{ocmin}$  and  $V_{ocmax}$  are the open circuit voltages with least and maximum qualities (360V and 440V) under completely released and completely charged conditions of battery system which is  $\pm 10\%$  of  $V_{oc}$ . The battery is intended to give 10kWh for the duration of the day with  $C_b=1125F$ ,  $R_b=10kw$ ,  $R_s=0.1w$ , and  $V_{oc}=400V$ .

**IV. FUZZY LOGIC CONTROLLER**

Fuzzy logic is a complex mathematical method that allows solving difficult simulated problems with many inputs and output variables. Fuzzy logic is able to give results in the form of recommendation for a specific interval of output state, so it is essential that this mathematical method is strictly distinguished from the more familiar logics, such as Boolean algebra. This paper contains a basic overview of the principles of fuzzy logic.

*Fuzzy Logic System*

Today control systems are usually described by mathematical models that follow the laws of

physics, stochastic models or models which have emerged from mathematical logic. A general difficulty of such constructed model is how to move from a given problem to a proper mathematical model. Undoubtedly, today's advanced computer technology makes it possible; however, managing such systems is still too complex.

These complex systems can be simplified by employing a tolerance margin for a reasonable amount of imprecision, vagueness and uncertainty during the modeling phase. As an outcome, not completely perfect system comes to existence; nevertheless, in most of the cases it is capable of solving the problem in appropriate way. Even missing input information has already turned out to be satisfactory in knowledge-based systems

Fuzzy logic is a type of numerous esteemed rationales in which reality estimations of variables might be any genuine number somewhere around 0 and 1. By differentiation, in Boolean rationale, reality estimations of factors may simply be 0 or 1. Fuzzy rationale has been extended to deal with the possibility of halfway truth, where reality quality may stretch out between totally genuine and totally false. In addition, when etymological factors are used, these degrees may be supervised by specific limits.

Normally fuzzy rationale control system is produced using four significant segments displayed on Fig.3 fuzzification interface, fuzzy induction motor, fuzzy logical structure and defuzzification interface. Each part nearby essential fuzzy rationale operations will be depicted in more detail below.

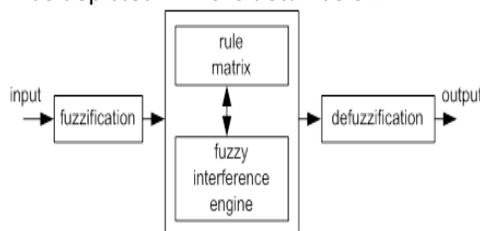


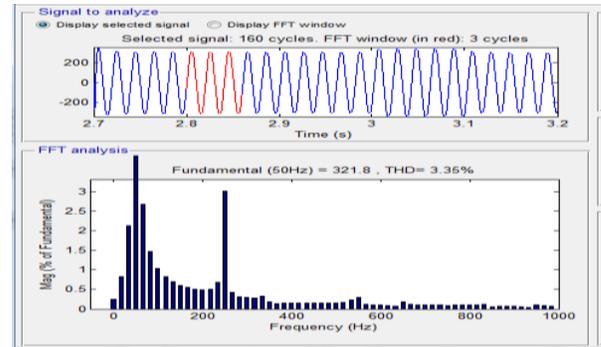
Fig.3: Fuzzy logic strategy system

The fuzzy rationale investigation and control systems showed up in Fig.3 can be depicted as:

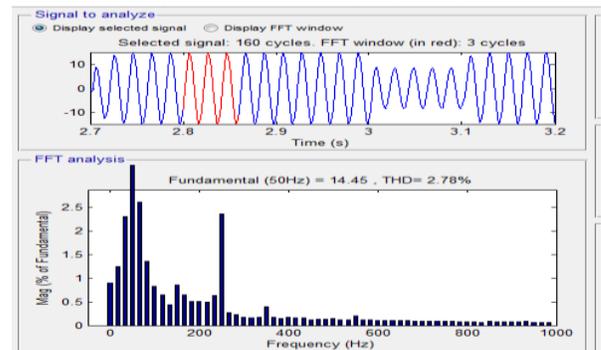
- 1.Receiving one or extensive number of estimations or other evaluation of conditions existing in some system that will be dismembered or controlled.
- 2.Processing all got inputs as indicated by human based, fuzzy "expecting then" norms, which can be conveyed in fundamental dialect words, and combined with routine non-fuzzy get ready.

3.Averaging and weighting the results from all the individual standards into one single output decision or sign which picks what to do or advises a controlled system what to do. The result output sign is a correct defuzzified esteem. Above all else, the distinctive level of yield (fast, low speed and so on.) of the stage is characterized by determining the enrollment capacities for the fluffy sets.

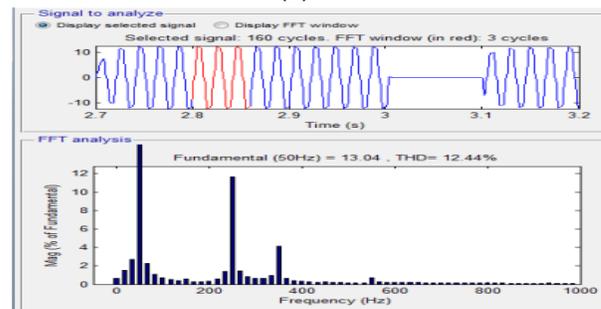
V. SIMULATION RESULTS



(a)



(b)



(c)

Fig.4: Waveforms and harmonic spectra (a) Line 'bc' voltage of at PCC (b) Phase 'b' input current and (c) Phase 'b' Load current

Fuzzy logic controller results:

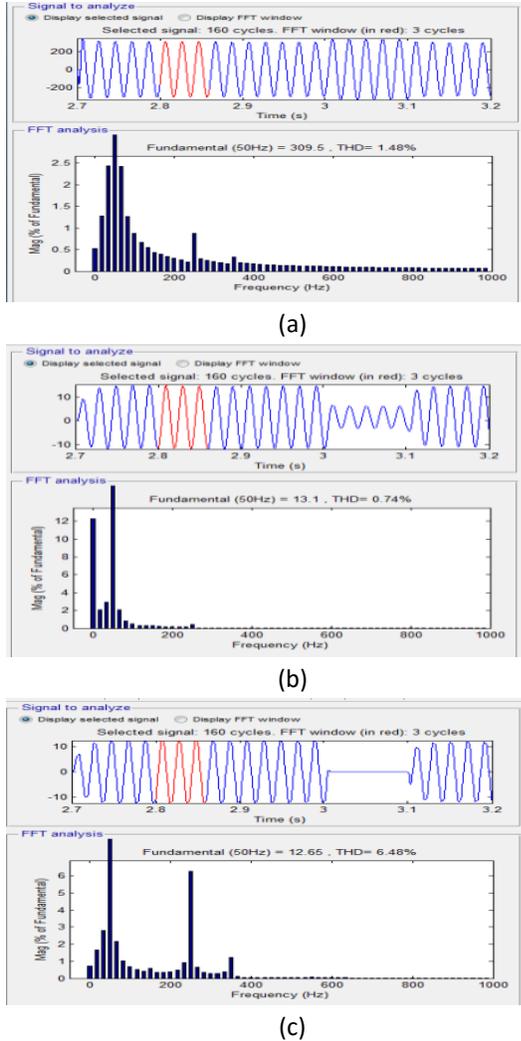


Fig.5: Waveforms and harmonic spectra (a) Line ‘bc’ voltage of at PCC (b) Phase ‘b’ input current and (c) Phase ‘b’ Load current

The signal to signal analysis and FFT analysis of  $V_{sbPFC}$ ,  $I_{sbPFC}$ ,  $I_{lbPFC}$  are shown in the above Figures. Fundamental frequency and THD can also be observed.

### VI. CONCLUSION

A microgrid has been designed and its performance is simulated in MATLAB Simulink. This has been found suitable to serve for remote and isolated places where the main-grid is not accessible. The wind power generation has been achieved by PMBLDC generator. Its trapezoidal EMF has helped to convert AC power into DC power using 3-phase rectifier with less ripples and has given an economic solution for WECS by replacing one VSC with a diode

bridge rectifier. BPF algorithm using fuzzy logic controller for VFC has provided harmonics elimination of the supply, voltage regulation, load leveling. MPPT controller has extracted maximum power using a boost converter and feeds to the battery and loads. During low wind conditions, battery and DG take care of load demand. A comparison of simulated results of BPF based fuzzy logic controller gives the better performance compared to BPF based PI controller.

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