POWER MANAGEMENT STRATEGY IN DISTRIBUTED POWER GENERATION SYSTEM USING NEURO FUZZY LOGIC CONTROL

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ABSTRACT:

There are many challenges involved in integrating distributed generation (DG) systems using renewable energy sources (RES) into the electrical grid, including problems with synchronisation, control, power management (PM), and power quality. Under grid failures and harmonic distortions, the amplitudes of active and reactive power oscillations are also reduced and controlled by a single flexible control parameter. The ability to load at inverter power capacity during grid disruptions and inject maximum active power and minimum reactive power into the electric grid is one of the significant improvements over earlier studies in a similar area. In order to operate three-phase inverters and manage power flow between DG sources, the electric grid, and load demand under balanced and unbalanced grid situations, a power management technique based on references current generators (RCGs) is proposed in this study. In addition, as compared to traditional current regulation controllers in SRF, the introduction of a neuro-fuzzy controller to a grid inverter for quick transient response and zero steady-state faults. These proposed controllers will be implemented in MATLAB/Simulink and the outcomes will be compared.

Keywords: PV System, Wind Energy System, Neuro-Fuzzy Controller, DAF-PLL and Power Management Strategy etc.,

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1. INTRODUCTION:

The shortcomings of conventional electricity generating have made distributed generation (DG) very important. Commercial loads that need ongoing management can receive more efficient, higher-quality, and reliable power from the DG system. By managing a grid current, the grid-associated converter in a distributed system typically provides the primary grid with flexible and responsive electricity. Currently, least square error is used using a proportional resonant controller. A proportional integral (PI) control mechanism is employed for the active dampening of the LCL filter or for high dynamic performance in rapidly changing atmospheric circumstances [1].

The compensation equations for voltage sag/swell or in any severe current references are taken into consideration for supplying active and reactive powers to the grid in accordance with the grid connection criteria if any fault occurs in the main grid system. The DG system being detached from the main grid and operating in the islanding operation mode is another possible option during grid fault scenarios [2]. The DG system can switch from voltage control mode to current control mode during this islanding operation in order to supply the desired voltage to the nearby sensitive loads. The DG system resumes grid-connected operation as soon as the main grid voltage returns to normal.

In general, the generation of power was becoming increasingly difficult due to the rise in power demand brought on by increased population and usage. Because non-conventional energy sources are used so frequently as a distribution energy source, there may be stability issues including voltage regulation and other power quality issues. Because of this, forced commutated converters based on power electronics are chosen in distribution systems to preserve system stability, dependability, and efficiency while also enhancing the quality of power at coupling junction points. This inverter controller selects the reference signals it needs from the grid system.

2. PROPOSED STRUCTURE OF HYBRID SYSTEM

Figure 1, shows the structure of grid interfaced hybrid system. This hybrid system consists of combination of wind and PV energy systems.

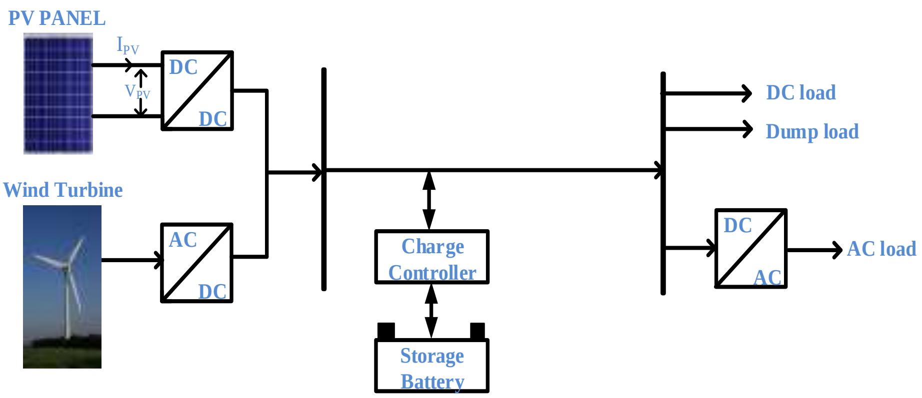

Figure 1: Structure of Grid Interfaced Hybrid System

For both PV and wind energy systems, this structure comprises of dc-dc converters to maintain consistent output from the systems [16]. A battery energy system was also installed in this construction to increase the consistency and dependability of supply to the load demand. Using a PWM-based inverter, PV, wind, and battery systems are connected through a DC-bus and converted to AC. This PWM controller's major objective is to keep the grid and hybrid system in sync [16].

Photovoltaic System:

The structure of PV system with mppt controller is shown in figure 2. Photovoltaic system plays a key role in the present distributed energy source as it is freely available in nature and has better energy efficiency out of all energy sources. PV panel converts solar irradiance into electrical energy. The main components of PV system are PV panel, Dc-Dc converter with MPPT controller [17]. Here, MPPT based boost converter is designed to extract the maximum power from the PV.

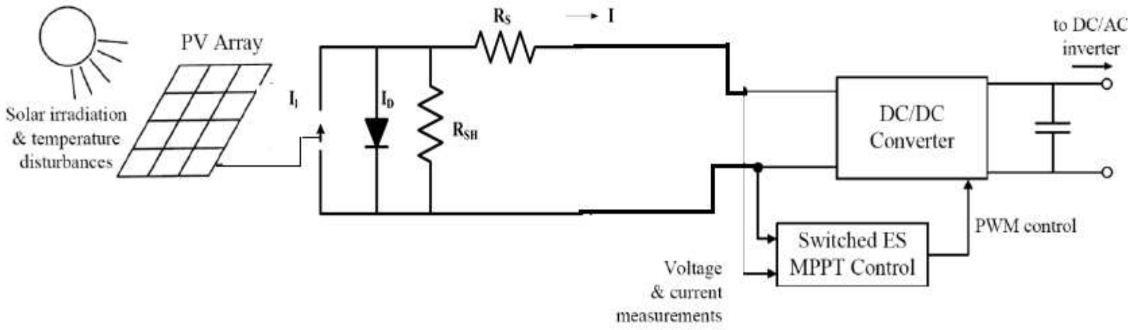

Figure 2: Line Diagram of PV System with Dc-Dc Converter

$$I_1 = I_{p1} - I_{aD} - I_{ash}$$

$$I_a = I_{aph} - I_{ao}[e^{(\frac{qV_{aD}}{nKT})}] - (\frac{V_{aD}}{R_{as}}) \quad (1)$$

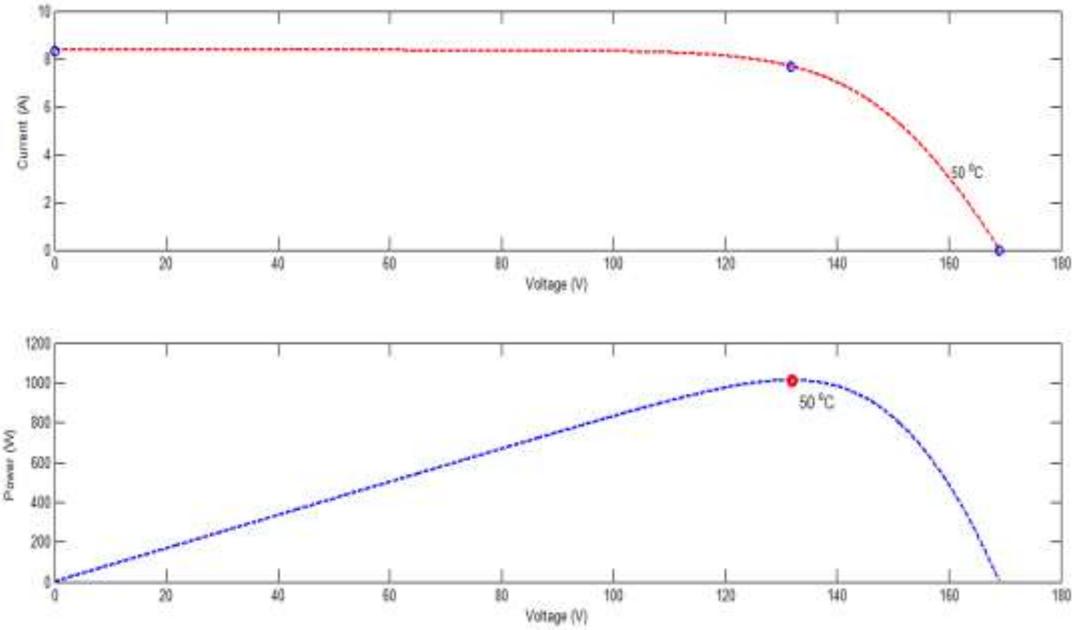

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Figure 3: V-I Characterestics of PV system

Figure 3 depicts the P-V and I-V characteristics of a solar system. This allows for the identification of the system's maximum power point. Figure 5 [18] depicts the construction of the closed loop control diagram from the DC-DC converter. Here, the duty cycle for the dc-dc converter is produced by the PWM converter using the comparison between the PV system voltage and the reference signal from the MPPT.

Wind Energy System:

Wind turbines are the other substitute for the renewable energy system. A gearbox mechanism is utilised in W.E.S to sustain high speed from the wind turbine, which transfers wind speed energy to kinetic energy. This gearbox applies to a synchronous generator (induction generator) that transfers low speed shaft to high-speed shaft for electrical generating [19]. SGIS and DFIG are the two main types of induction generators. The primary benefit of using an induction generator in a wind turbine is that it produces electricity at varying speeds, is easy to manufacture, and can recycle spent rotor power with the use of back-to-back converters. To get the most power out of the W.E.S, it is additionally integrated with a DC-to-DC boost converter based on mppt.

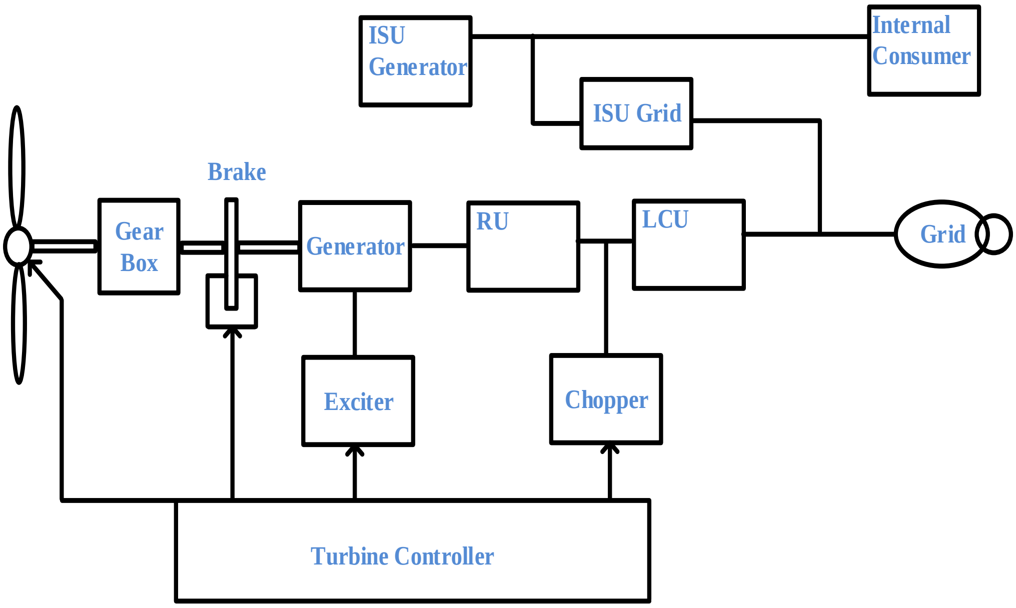

Figure 4: Wind Turbine Architecture

The low-speed shaft is converted into the high-speed shaft via the gear box and then used to drive the generator. The Line Control Unit (LCU), which is used to regulate the wind output to satisfy grid requirements, is attached to the generator's output after it has been converted to dc using a rectifying unit [20]. The Internal Supply Unit (ISU), a separate unit, is used to provide electricity to a wind turbine's internal auxiliaries (such as a motor, battery, etc.).

The mathematical analysis for wind energy system is expressed in equation (2) and coefficient of power in equation (3).

$$P_{mech} = 0.5\rho AV^3 C_p \qquad (2)$$

Where, C_P is the coefficient of power

$$C_p = 0.53(\lambda - 0.2)(0.7 - \lambda) \qquad (3)$$

3. FUEL CELL MATHEMATICAL MODEL

The electrochemical in cell begins on the anode side, where flow plate channels carry H2 molecules. Catalyst in anode separates hydrogen on protons H+ via membrane that proton travels to cathode and electrons that flow to cathode via external circuit. The use of a catalyst at the cathode allows oxygen to mix with hydrogen protons and electrons to generate H2O and heat. This reaction is represented by the equations [8] [9].

$$H_{2a} \rightarrow H_{2a}O + 2e^-(Anode)$$

$$\frac{1}{2}O_{2a} + 2H^+ + 2e^- \rightarrow H_{2a}O(Cathode)$$

$$\Delta g_g = \Delta g^o{}_f \; - RT_{fc}[\ln(PH_2) + 0.5\ln(PO_2)]$$

$$E = -\left(\frac{\Delta_{gf}}{2F}\right)$$

$$V_{act} = V_0 + V_a(1 - e^{-C_1 i})$$

Fuel Cell Equivalent Electric Circuit

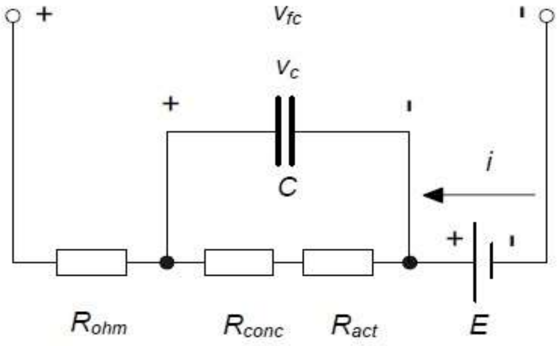

Figure 5: equivalent circuit for fuel cell system

$$V_{fca} = E_a - V_{ac} - iR_{aohm}$$

$$C_a \frac{dV_{aC}}{dt} + \frac{V_C}{R_{aact} + R_{aconc}} = i_a$$

$$V_{afc} = E_a - \left(\frac{R_{aact} + R_{aconc}}{\left(sc\left(R_{aact} + R_{aconc} + 1\right)\right)} + R_{aohm} \right) i_a$$

Proposed PNS extractor:

In grid-connected systems, nonlinear adaptive filters (AF) ensure quick tracking of the amplitude and phase angle of the input signal. This filter has numerous advantages, including generality, reduced complexity and computing weight, and near-optimal performance even under non-stationary and asymmetric situations. In this research, a new enhanced PLL approach based on adaptive filter assures quick dynamic response and reduces errors under adverse grid conditions to solve the disadvantages of the classical PLL.

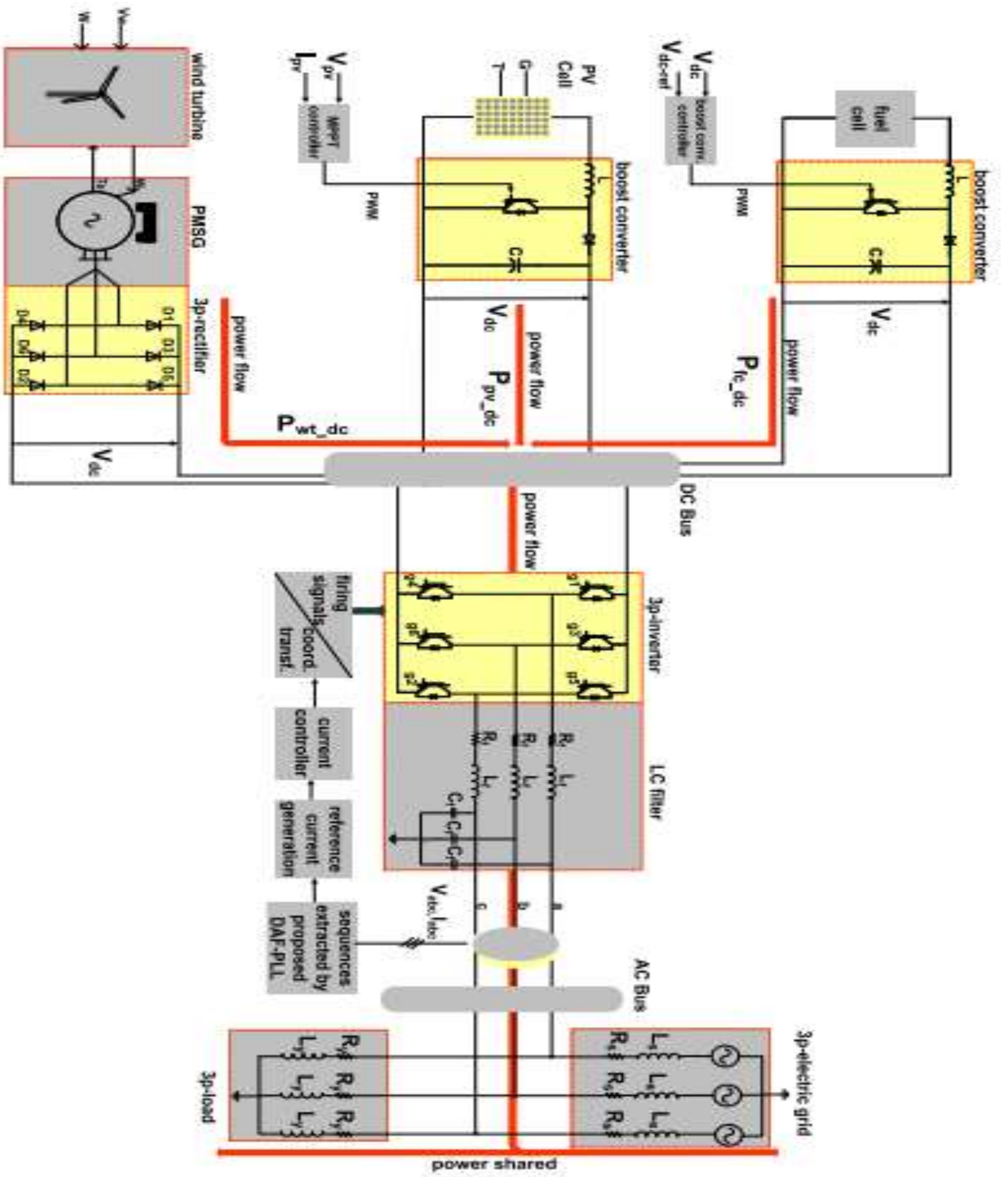

Figure 6: Proposed PNS Converter

To generate reference current signals, PNS signals generated by an upgraded dual adaptive filter-based PLL (DAF-PLL) were used. From the input signal Vp, the improved single-phase AF-PLL extracts the output signal V, its amplitude Apl and phase. The phase error is the computed difference between the input and output signals.

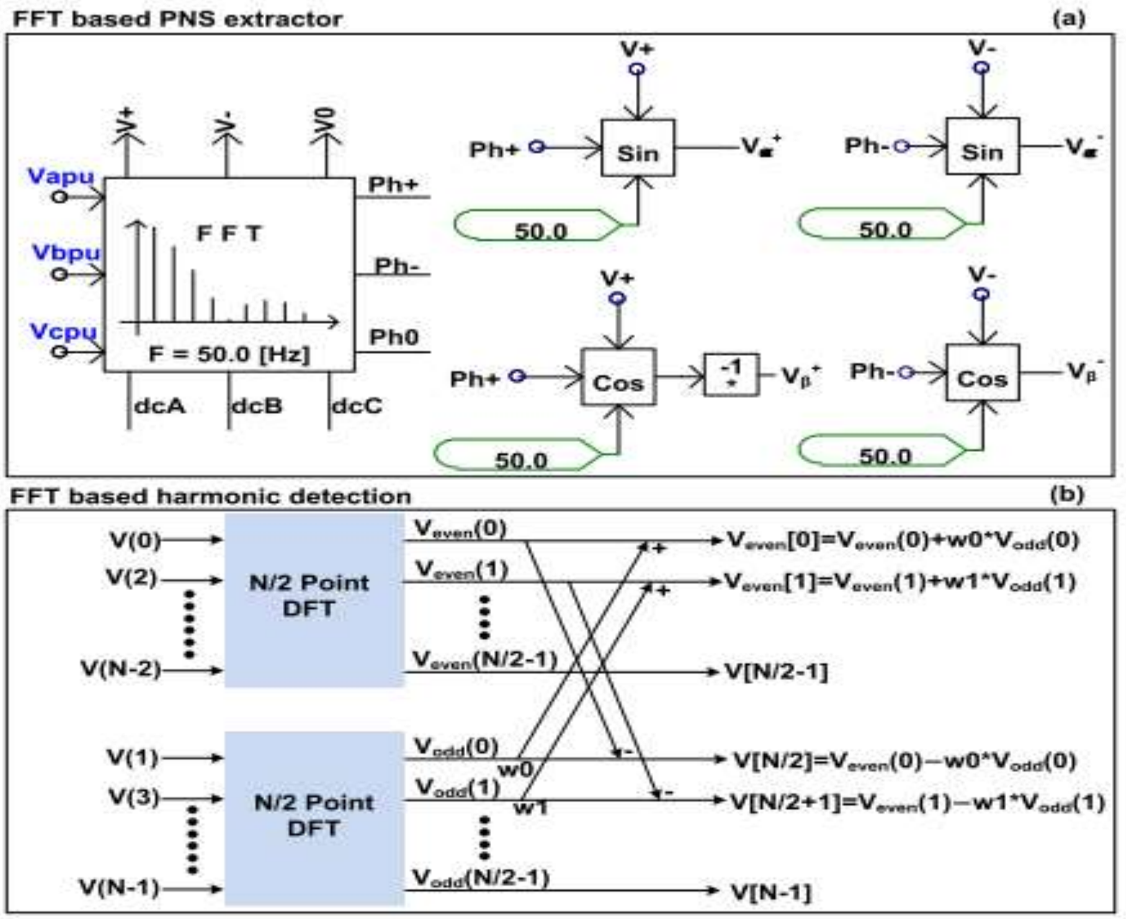

Figure 7: FFT for, (a) PNS components seperation (b) harmonic detection.

The gain parameters k1, kp and kv are chosen as the best values for the proposed PLL's dynamic response. For tweaking parameters, the following components are indicated.

• Raising the value of k1 improves dynamic response. However, it causes signal oscillations.

•

4. ANFIS CONTROLLER

Fuzzy Logic Controller:

Mathematical analysis involving numerous variables and constant interfacing is the primary source of complexity in conventional PID controllers. This work uses a fuzzy logic controller, a type of soft computing controller, to address these problems. One sort of artificial intelligence is fuzzy logic, which is based on information that is either true or untrue. A function or collection of flexible if-then rules is known as FLC [22].

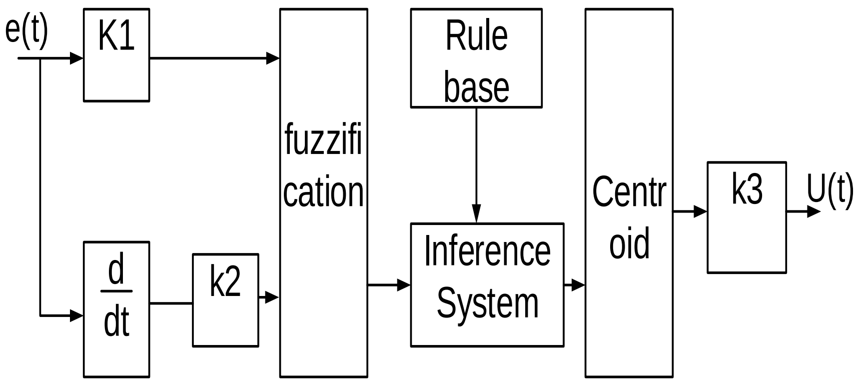

Figure 8: Fuzzy Inference System Architecture

Figure 8 depicts the basic structure of a fuzzy controller with two inputs: one as dc voltage error and second one change in error. The five memberships that make up each FLC input are SM, SL, ZE, HL, and HM. In order to test firing the set of IFTHEN rules, the minimum of the two inputs of SM, SL, ZE, HL, and HM is picked. If the error input is Z and the error input change is H, the output is MH.

e/ce	SM	SL	ZE	HL	HM
SM	SL	SM	ZE	HL	HM
SL	HM	HL	ZE	SL	SM
ZE	SL	ZE	HL	HM	SM
HL	SL	SL	SM	SL	SL
HH	SL	ZE	HL	HL	HM

Table 1 Rule-Base formation analysis table

Ann Controller:

Figure 9 illustrates the fundamental components of an artificial neural network. A hidden layer is represented by a circle, and an adaptive node by a square. It does away with the necessity for the rules obtained from if-then expressions by displaying hidden layers between the input and output layers; these nodes act as membership functions. We'll suppose the examined ANN has two inputs and one output for the sake of simplicity. The weight matrix W in this network connects every neuron to every element of the input vector p.

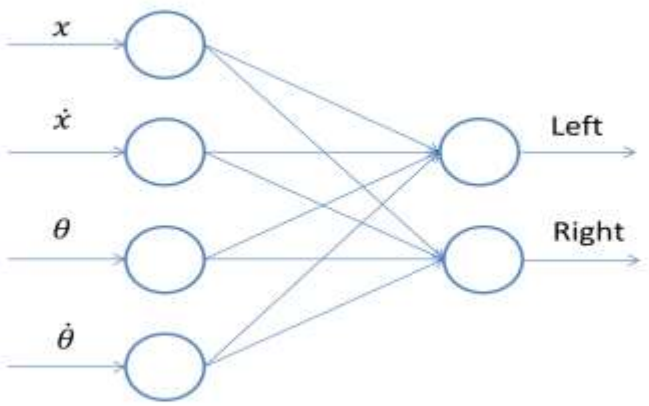

Figure 9: Multi-Layer Neural Network

5. RESULTS& DISCUSSION

The proposed hybrid system using PSO MPPT controller and P&O MPPT controller strategies for inverter optimization techniques is tested and verified in Matlab/Simulink Environment. Tables 1 and 2 display the design parameters for wind and photovoltaic systems, respectively. The system parameters needed for a PV system are listed in Table-2. Three separate situations are used to test this suggested system.

Parameter Variable	Value
P_{max}	1800W
V_{max}	140V
Current at P_{max}	11.8A
V_{oc}	148V
I_{sc}	12.74A
L_{boost}	Lb=2.0 mH
C_{fil}	Cs=860 µF/450Vdc
C_{dc}	C_{BUS}=560 µF/550 Vdc
f_{sw}	fSb=25 kHz

Table -2: System Parameters for PV System

According to the modelling expressions shown in the preceding parts, the solar and wind systems in this are designed. The wind energy system is intended to produce 20kw, and the solar plant is intended to produce 16kw. The power management approach for various load conditions is displayed.

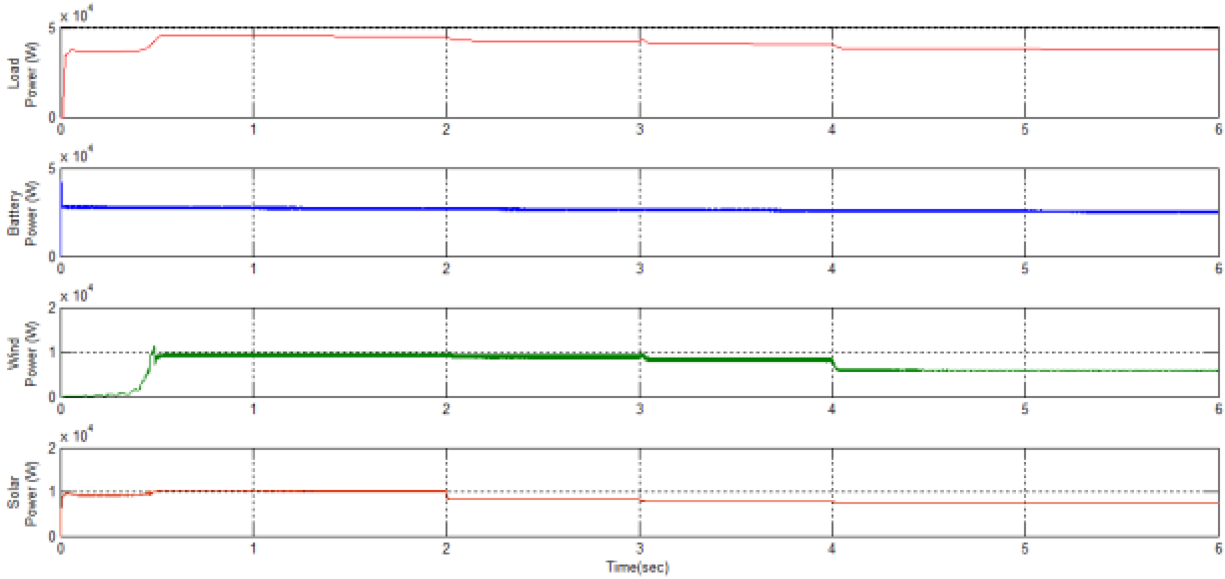

Figure 10: waveform of (a) Load Power, (b) Solar Demand, (c) Grid Power and (d) Battery Power

S.NO	Waveform	Range(kw)
1	Load Power	49kw
2	Battery Power	20 kw
3	Wind Power	10 kw
4	Solar Power	10 kw

Table -3: System Power Specifications using PI Controller

Figure 10 displays the power management strategies for the proposed system based on the simulation results. Here, the PV, battery, and wind systems are chosen for load sharing based on their respective generations. The solar system produces 8kW between 2s and 6s and 10kW between 0s and 2s. And the wind system produces 9.8kW between 0 and 4 seconds and 6kW between 4 and 6 seconds. This system requires a load of about 47kW, which is altered to 38kW for the duration of 3 to 6 seconds. Figure 11 displays the power management strategies for the proposed system under ANFIS controller.

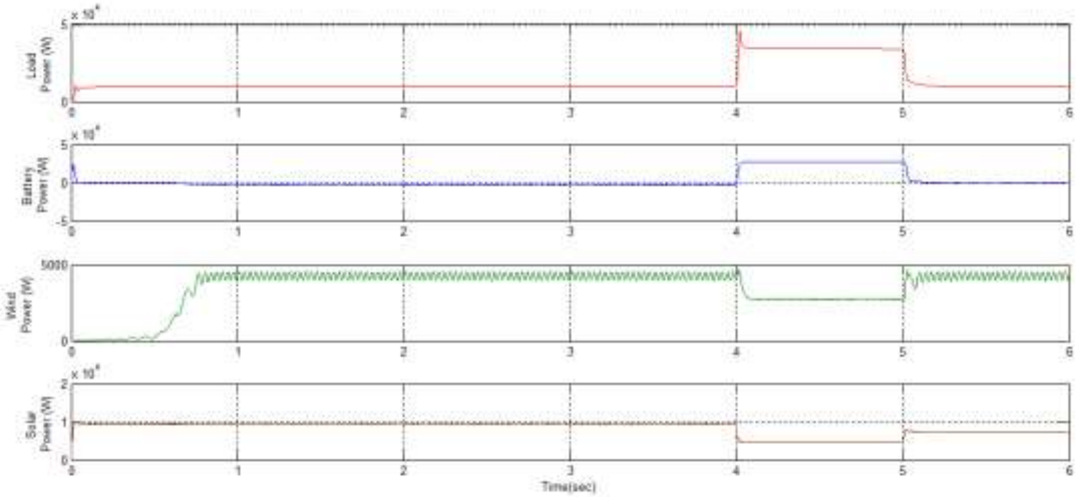

Figure 11: Waveform of (a) Load Power, (b) Solar Demand, (c) Wind Capacity and (d) Battery Power using ANFIS Controller

SNO	Waveform	Range (kW)
1	Load Power	48kW
2	Battery Power	22kW
3	Wind Power	10kW
4	Solar Power	10kW

Table -4: System Power Specifications using ANFIS Controller

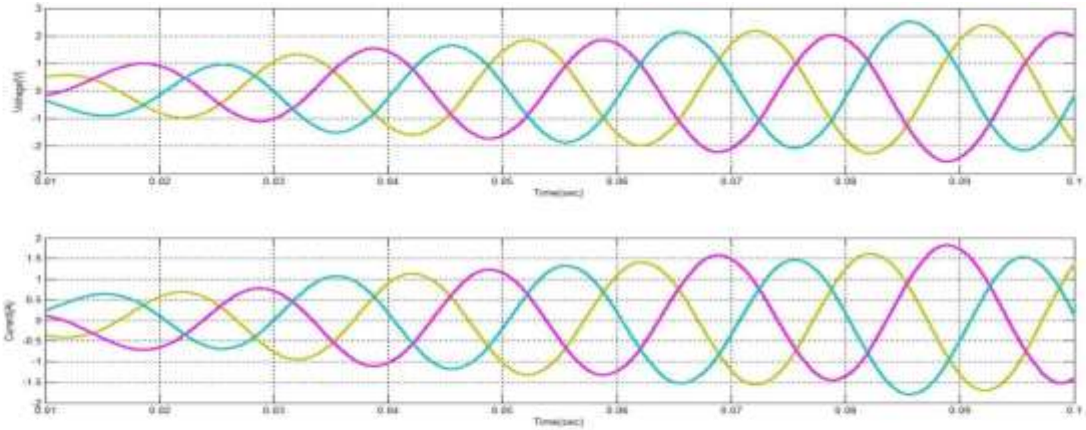

Figure 12: Simulation waveform for Inverter Voltage and current using ANFIS

S NO	**Waveform**	range
1	PV Inverter Voltage	220 V
2	PV Inverter Current	10 A

Table -5: Inverter Output Specifications using ANFIS Controller

The wave forms of inverter voltage and current under anfis controller is shown in figure 12. The measured power factor after inverter with PI and ANFIS controllers are shown in figure 13 & 14.

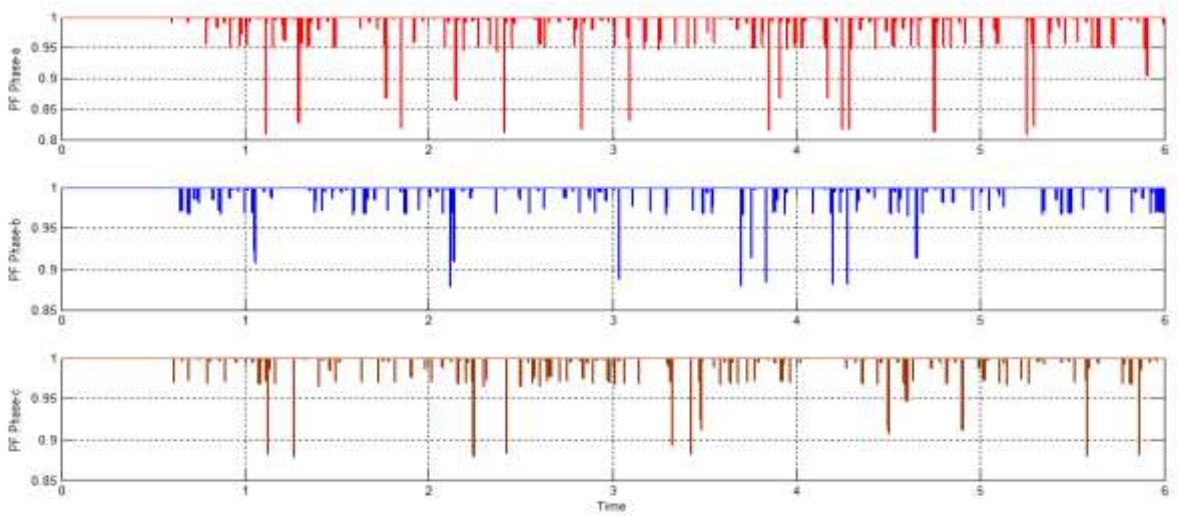

Figure 13: Simulation waveform for Power Factor using PI controller

S NO	Waveform	Range
1	Inverter PF Phase A	0.8
2	Inverter PF Phase B	0.85
3	Inverter PF Phase C	0.85

Table -6:Power Factor Specifications using PI Controller

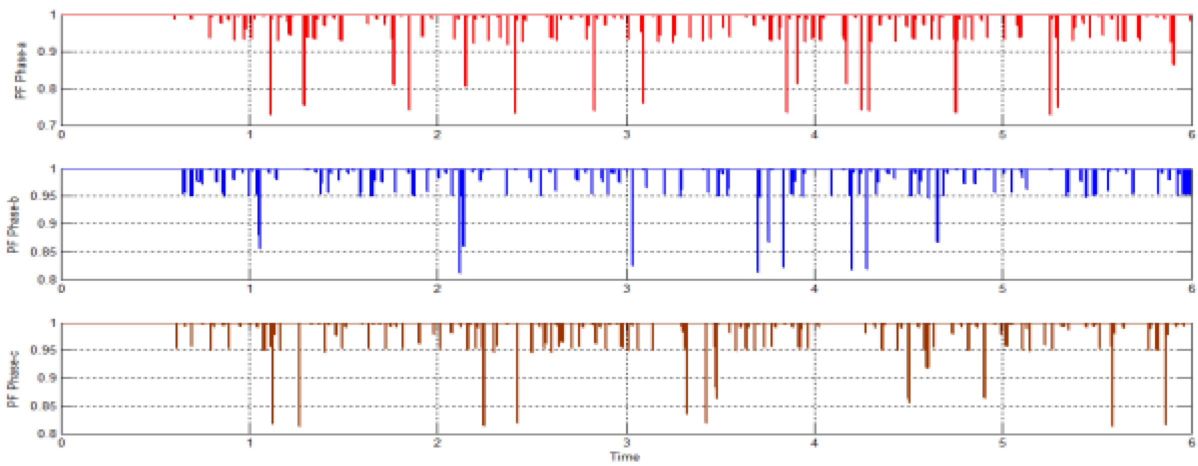

Figure 14: Simulation waveform for Power Factor using ANFIS controller

S NO	Waveform	Value
1	Inverter Power Factor Phase A	0.85
2	Inverter Power Factor Phase B	0.9
3	Inverter Power Factor Phase C	0.9

Table -7: Power Factor Specifications using ANFIS Controller

SNO	PARAMETERS	WITHOUTCONTROLLER THD in (%)	WITH PICONTROLLER THD in (%)	WITH ANFISCONTROLLER THD in(%)
1	LOADVOLTAGE	8.97	7.83	4.30
2	LOADCURRENT	10.23	8.49	4.23
3	INVERTERVOLTAGE	10.23	8.49	4.30
4	INVERTERCURRENT	9.32	7.78	4.22

Table 8: Comparison of THD Values (with and without ANFIS controller)

The comparative analysis of power factor and THD for load voltage and current with and without controllers are mentioned in table-8.

6. CONCLUSION

A hybrid system with photovoltaic (PV) - wind and battery backup to meet reliable power supply demands was proposed in this study. The solar system is designed for 16 kW of power, and the wind energy system is designed for a rating of 20kW and has the capability to maintain power management to share the load demand under various variable conditions. Both the PV and wind systems were implemented using MPPT-based DC-DC converters to improve the efficiency and reliability of the proposed system. We propose PO MPPT techniques. To improve the performance of PV-Hybrid and improve the power quality problems an ANFIS controller is implemented. The proposed MPPT-based hybrid system was tested and verified using the MATLAB/Simulink software.

To achieve better and accurate result, the proposed hybrid system can control with optimization techniques.

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