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Operation and Control of the Distributed Energy Resources to Improve the Power Quality in Electrical Distribution System Using Hbmo -Ann - A Novel Control Algorithm

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Abstract

Objectives: To propose a novel hybrid control plan to enhance the power quality (PQ) of distributed energy sources (DERs) such as solar energy (SE), wind energy (WE), and battery energy storage system (BEES) technologies. **Method:** A BEES, a PV farm, and a wind farm are integrated into the grid to supply home loads. The ABMO-ANN control system is a novel method that combines the Hybrid Barnacles Mating Optimization Algorithm (HBMO) and the Artificial Neural Network (ANN) (ANN). The power is balanced by balancing the power consumed by BEES and the power provided by the VSI inverter in this new proposed algorithm. **Findings:** In this HBMO-ANN control model, the proportional integral (PI) gain parameter controller generates the signals based on the load variation to manage the hybrid RES energy sources optimally. The assumed variables as system parameters in this suggested prediction approach are direct current (DC) voltage and active with reactive power. **Novelty:** The new HBMO-ANN method creates optimal control, aiming to improve power system damping and sustain line voltage with the reactive power compensation provided. However, when compared to existing control methods, the performance of the HBMO-ANN approach with a PI controller is also justified. The suggested methodology is compared to existing methods in MATLAB/Simulink.

Keywords: Power quality improvement; Renewable energy sources; Hybrid Barnacles Mating Optimization Algorithm; Reactive power; Power system

1 Introduction

The integration of renewable energy sources is growing at a high rate because of electricity load demand and technological innovation. They're fed to the network via a power converter system that includes a DC/AC converter, a Maximum Power

Point Tracker MPPT, a filter, and control systems, but the current injected should be sinusoidal with low harmonic distortion (THD) of less than 5%, according to the international standard IEEE std 929-2000. MPPT performance is an important aspect of the characterization of PV inverters since PV systems should always harvest the maximum energy available from the PV generator.[1]. With a 17 percent yearly increase, wind energy now accounts for around 4.4 percent of global power. The incoming wind moves the rotor blades, and the rotational energy is converted to electrical energy through an AC–DC–AC converter in a generator. The principal source of output voltage wave distortion appears to be the behavior of the power switches in the converter interfaces that make up the WECS. THD reduction and an appropriate control switching system for power converters are two issues that need to be addressed. The suggested work on the ANN inverter control algorithm for wind energy conversion systems is shown here, with the goal of improving output power quality by removing harmonics[2].

A battery energy storage system (BESS) is an electrochemical device that charges (or gathers) energy from the grid or a power plant, then discharges it as needed to deliver electricity or other grid services. When it comes to load levelling, the energy storage system can help with voltage management as well as minimizing low voltage network disturbances. When it comes to the island network, it is regarded to be a useful solution for supplying critical loads when distribution lines are entirely cut off, allowing the network to continue running and so increasing the reliability of the power system.[3]. Solar, wind, and hydroelectricity are all being evaluated as feasible possibilities for satisfying energy needs. For many years, adaptive AC transmission system (FACTS) equipment has been used in energy efficiency, long-term equipment for efficient power consumption, and increased safety and reliability based on the utility of power phase[4]. Renewable energy sources, such as wind energy conversion systems, solar photovoltaic (PV) systems, and battery energy storage systems, were used in the most recent micro grid (MG) implementation. Both transmission and distribution networks use RESs, which are based on power electronic converters. This increases PCC and harmonics while lowering PQ issues[1–4].

Precise power quality (PQ) study encompasses the full power and electricity supply chain, from generation through distribution and evaluation. Voltage sags, breakdowns, swelling, harmonics, and imbalances all occur in the distribution system[5]. The control algorithm plays an increasingly significant factor in improving system power quality and efficiency as topologies grow more low-cost, high-efficiency, high-reliability, and high-tolerance. As a result of the data, it is apparent that the swings and changes in the economy are real. ripples in the output powers are decreased as compared to other algorithms with the controller. But the fluctuations are very large with PI control as compared to algorithms tuned control techniques. Optimization is the process of finding the best a set of factors or parameters that satisfy the restrictions in order to attain the goal function, whether it's for reduction or optimization. The objective function is usually expressed in terms of cost, efficiency, profits, or other factors based on the applications or issues to be solved. The proposed algorithm solves optimization problems by mimicking the mating rituals of barnacles in nature. To test the properties of BMO in obtaining optimum solutions, it is initially tested on a set of 23 mathematical functions[6].

This manuscript presents a hybrid control scheme for the PQ improvement for hybrid RES such as PV, wind energy hybrid scheme in grid and off grid mode. The suggested method is the consolidation of Barnacles Mating Optimization Algorithm (BMO) and Artificial Neural Network (ANN) and hence it is said to be as HBMO-ANN control scheme. The remaining segment of this manuscript is designed as: Segment 2 explains the power quality improvement topology with hybrid renewable energy sources. Segment 3 illustrates the proposed hybrid approach using ABMO-ANN Control Scheme. Segment 4 presents the results obtained through simulation using different algorithms. Finally, Section 5 concludes the proposed research work.

2 Methodology

2.1 Modelling of DERs for Power Quality studies

2.1.1. Modeling of WTG

Wind turbine is designed to convert the wind energy into electric energy, with all control circuits and gearbox that convert the rotational low speed into electric power. Understanding of wind properties is very important for wind energy exploitation. Speed of wind is highly variable both geometrically from place to place and temporally, seasonal and in hourly means. These variations are called synoptic variations, and they have a peak at around 4 days. wind speed will be determined by the seasonal, synoptic and diurnal effects, which varies on a time, with turbulence fluctuations superimposed.

Wind turbine captures energy with the following equation

$$P = 0.5C_pV^3A \tag{1}$$

Where: P = Mechanical power in the moving air (Watt). ρ = Air density (kg/m^3). A = Area swept by the rotor blades (m^2) V = Velocity of the air (m/s), Cp= Power coefficient

Tip speed ratio (TSR) of a wind turbine is defined as:

$$\lambda = \frac{\Omega R}{V} \tag{2}$$

Where: Ω = Mechanical speed at the rotor shaft of the wind turbine (rad/s) R = Radios of the blade (m). V = Velocity of the air (m/s)

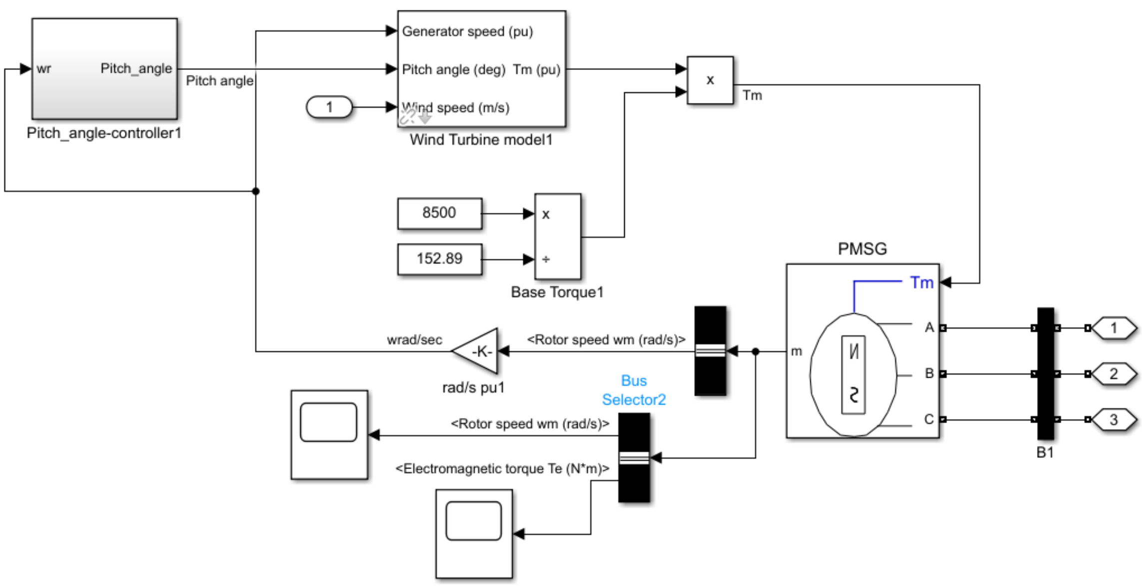


Fig 1. Modeling of WTG

2.1.2 Modeling of solar pv

PV cells are clustered into significant part to arrange PV modules, which can be related in blend of series and lined up with plan of PV exhibits, later that is worked as PV electrical source.

The V-I highlight condition of a PV cell is conveyed as module photocurrent (I_{ph})as follows

$$I_{ph} = \frac{[(I_{sc} + K_i\,(T - 298))\,I_r}{1000} \tag{3}$$

Where,

I_{ph} - photocurrent (A);

I_{sc} - short circuit current (A);

K_i - short circuit current of cell at 25○C and 1000W/m^2;

T - temperature operated in kelvin;

Irradiation of solar in W/m^2

Reverse saturation current Module I_{rs} is given by

$$I_{rs} = \frac{I_{sc}}{[exp(qV_{oc}N_s knT) - 1]} \tag{4}$$

Where,

q=electron charge=1.6×10^{-19} C;

V_{oc} = open circuit voltage in volts;

N_s = number of cells connected in series;

n = Diode ideality factor;

k = Boltzmann's constant = 1.3805×10^{-23} J/K.

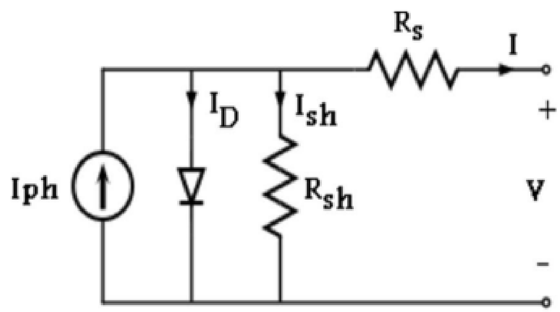


Fig 2. Equivalent circuit of PV cell

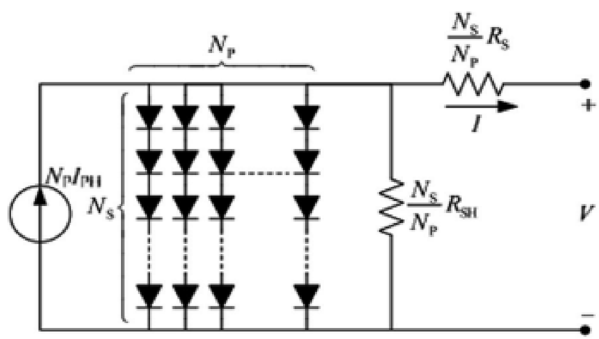


Fig 3. Solar array Equivalent circuit

The I_0 saturation current of module varies with the Temperature of cell, which is shown by

$$I_o = I_{rs}\left(\frac{T}{T_r}\right]^3 exp\left(\frac{qE_{go}}{nk}\left(\frac{1}{T}-\frac{1}{T_r}\right)\right] \tag{5}$$

$$I = N_p I_{ph} - N_p I_o \tag{6}$$

$$V_t = \frac{KT}{q} \tag{7}$$

$$I_{sh} = \frac{\frac{VN_p}{N_s}+IR_s}{R_{sh}} \tag{8}$$

Here: N_p: Parallel connection of PV modules in number; R_s: Resistance in series (Ω); R_{sh}: resistance in shunt (Ω); V_t: Thermal voltage of diode (V)

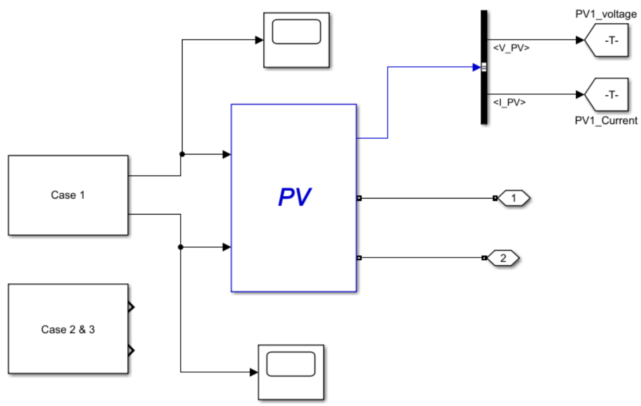


Fig 4. Modeling of solar pv

2.1.3 Modeling of BEES and data and technology

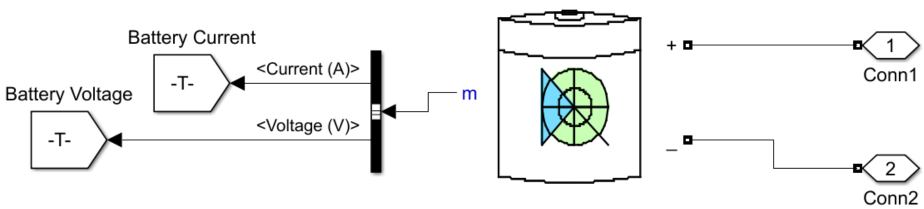


Fig 5. Modeling of Battery energy storage system

2.1.4 Inverter

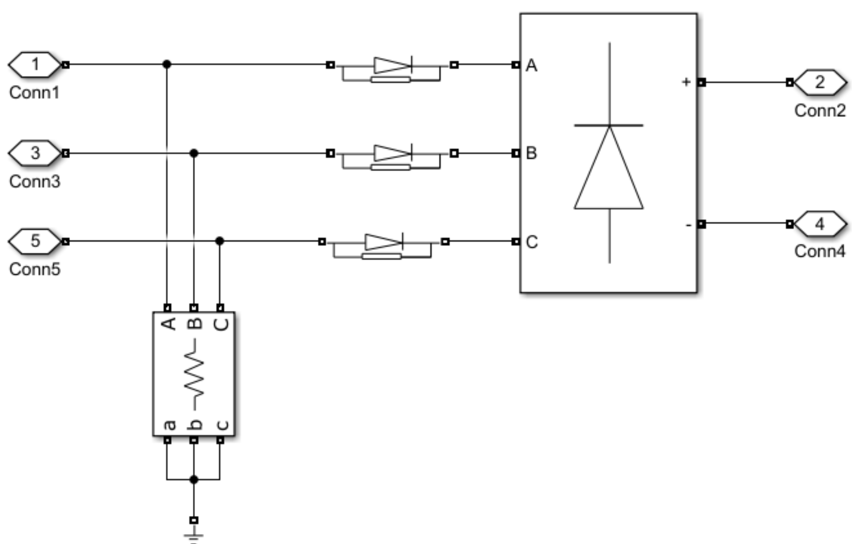


Fig 6. Modeling ofInverter system

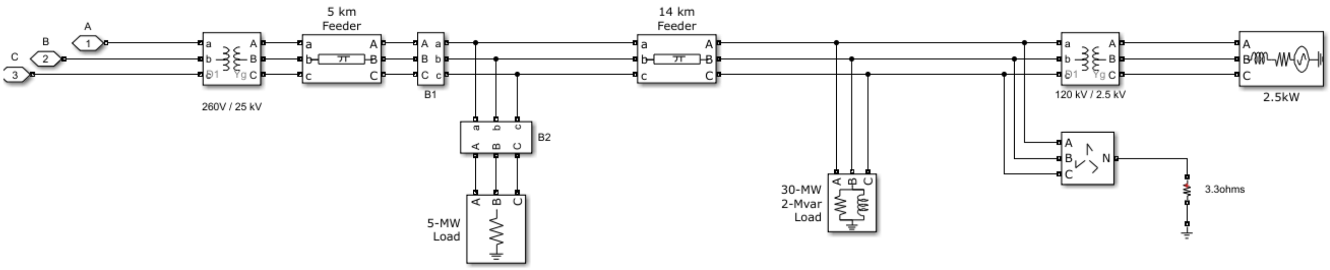


Fig 7. Gird system

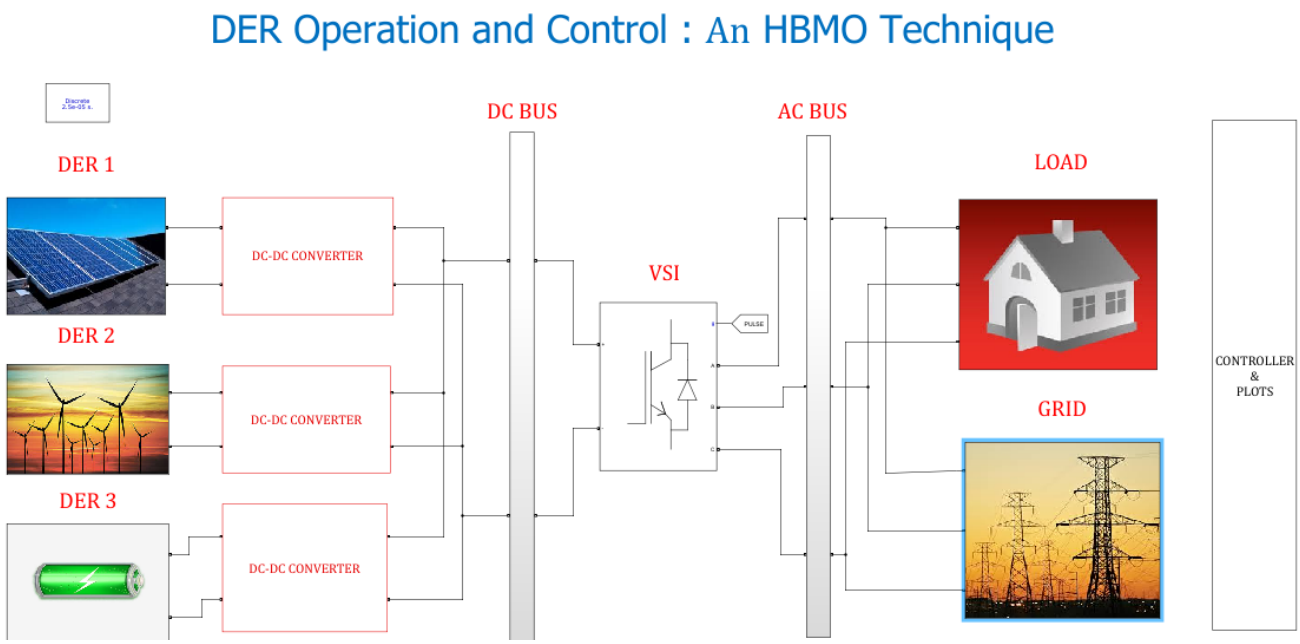


Fig 8. Proposed Test System

The closer AC waveform supplying voltages at the bus with rated currents, frequency [7] is represented by the electric power system. There are various terms for issues in the PQ. Only superior time scale concerns, such as voltage deviations (under/over-voltage), total harmonic distortion, and phase unbalance in voltage magnitude, are studied in this work [8].

2.2 PQ improvement Technologies

The various PQ improvement techniques are tabulated in Table 1 which provides complete overview of existing technology to mitigate the PQ issues and its contributions.

Table 1. PQ Technologies [9]

Sl. No.	Technology type	Methods	Results
1.	Applicability of PSO Technique to Mitigate Power Quality Problems	Selective Harmonic Elimination (SHE) technique based on PSO algorithm.	Eliminated 5th, 7th, 11th, and 13th output voltage and selected lower order harmonics
2	Compensators in Microgrid for Power Quality Enhancement	Virtual fundamental impedance (VFI) loop and variable harmonic impedance (VHI) loop	The active power-frequency (P-ω) droop controller and reactive power-voltage (Q-V) droop controller's performances are supported by VFI loop

Continued on next page

Table 1 continued

3	Role of APC in Power Quality Improvement	In microgrid, the AC bus is interfaced with renewable energy sources by an active power conditioner (APC). Hence, for the power quality enhancement, this APC has to be controlled	The current from the microgrid to become balanced and sinusoidal by making the APC to compensate the nonlinear load current
4	A novel control strategy with PI controllers and hysteresis control is projected	Compensating the current harmonics, correcting the power factor, and balancing the PCC supply voltage	THD of microgrid current to 3% Correction of power factor With the APC control, the degree of unbalance is less than 0.8% which is below the permitted level of 2% by international standards.
5	Power Quality Improvement with Controllers	DG employs a PI controller to generate the unbalance compensation reference for the microgrid DGs	The repetitive based voltage controller plays a major role in the synchronization of the microgrid and also generating and dispatching power in the microgrid under nonlinear and unbalanced load
6	Facts Devices in Power Quality Improvement	D-STATCOM that recognizes positive sequence admittance and negative-sequence conductance to regulate positive-sequence voltage and to overcome negative-sequence voltage.	Operation of DSTATCOM with other devices, multiple DSTATCOMs are implemented together to restore the voltage

2.3 Voltage deviation

The magnitude of voltage in a bus could diverge from their rated value. These variations are mostly permitted for tiny proportion but if they exceed few limits and described as disruptions. When magnitudes of the three voltages is not equal and are not 120 degrees apart then the system is called as unbalanced 3 phase power system. Furnaces, traction systems, and other large inductive machines, also big single-phase loads drawing currents indicate the voltage unbalances between two phases some equipment may also be connected between two phases such that current is only drawn on two out of the three. For the other equipment's connected to the similar supply, this causes the higher loaded phases to experience a higher value of voltage drop, reduction in the voltage on those phases, or on any one phase. The general single-phase loads when unevenly distributed, the unbalance in the voltage can be observed across a 3-phase system. This is originally balanced at the time of construction but when additional circuits and any equipment added to it this unbalance occur more often. The voltage unbalance is because of the degradation or the PFC capacitor bank unit failure, and a fault can produce the temporary voltage unbalances in the supply network. These factors have increased because of the reactive PF abnormality in maximum voltage lines. The reactance to resistance ratio (X/R) is low in the line, when activated by micro grid at the Distribution level, and the voltage gets impact by increasing the active PF. With all these reasons the variation of voltage on MG will be maintained with in $\pm 5\%$ nominal value or example:

2.4 Harmonic Distortion

At grid voltage, this leads no sinusoidal waveforms. The optimal prevalence of non-linear power electronic devices together with a maximum of sensitive loads causes in several elements along security with appropriate function of electronic factors. Harmonic is nothing but maximize the overall losses for system. The maximal harmonics is comparatively released through active/passive filters or shortens by using of suitable modulation strategy in power electronics switches command. Moreover, low order harmonics are much efficient to filter without shortening concurrently the signal on fundamental frequency. To overcome this issues, harmonic cancellation methods are existing, but it is not normally cost-efficient also conceptually hard to execute. Here, the 2 vital calculations are described to choose the amount of harmonic distortion, also deal with it. First, the THD as RMS percentage of harmonic frequency components among the base frequency component for voltage and current as represented in [9].

$$\sqrt{THD_v} = \frac{\sqrt{V_2^2 + V_3^2 \ldots V_n^2}}{V_f} \tag{9}$$

$$\sqrt{THD_i} = \frac{\sqrt{i_2^2 + i_3^2 \ldots i_n^2}}{V_f} \tag{10}$$

The second calculations we developed to cope with harmonic distortion is described by the set of equations in (3-5) as follows

$$\alpha_T^{HD}\Big|iT = i = \sum_{l,Ty} p_{l,Ty,T}^{Lo\ ad}\Big|_{\&_{lT=i}} l_{Ty}^{THD} \forall T \tag{11}$$

$$\alpha_T^{HD}\Big|_{iT=i+1} = \leq \alpha_T^{HD,Li\ m}\Big|_{lT=i+1} \forall T \tag{12}$$

$$\alpha_T^{HD}\Big|_{iT=i} = \alpha_T^{HD}\Big|_{lT=i}\left(1-\lambda^{HD}\mathrm{Max}_L\, v_{l,T}^{THD}\right)_{lT=1} \forall T \tag{13}$$

2.5 Overview of BMO

The structure of the BMO algorithm involves three main steps that start with the initialization of the barnacles, then the mating process, and finally, the reproduction of the offspring. These steps are mathematically implemented in the next sections. [10]

2.5.1 Initialization of the barnacles

In the BMO, barnacles are randomly initialized based on control variables number N and the number of barnacles n as follows:

$$X = \begin{pmatrix} x_1^1 & \cdots & x_1^N \\ \vdots & \ddots & \vdots \\ x_n^1 & \cdots & x_n^N \end{pmatrix} \tag{14}$$

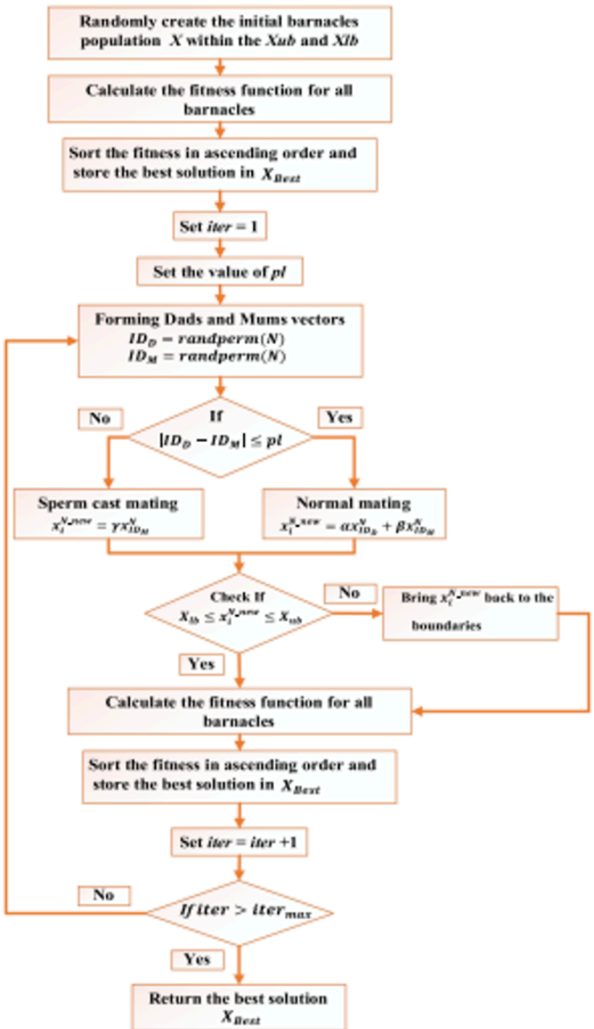
where the barnacles X should be within the boundary limits as:

$$X_{lb} \leq X \leq X_{ub} \tag{15}$$

where X_{lb} and X_{ub} are the lower and upper vector bounds, respectively, and can be expressed as:

$$X_{lb} = \begin{bmatrix} x_{lb}^1 & \ldots & x_{lb}^N \end{bmatrix} \tag{16}$$

$$X_{ub} = \begin{bmatrix} x_{ub}^1 & \ldots & x_{ub}^N \end{bmatrix} \tag{17}$$



Barnacles mating optimizer algorithm.

Initialize a set of random barnacles $X_i = (X_1, X_2, ..., X_n)$ within the limits $X_{lb} \le X_i \le X_{ub}$.
Calculate the objective function for each search barnacle.
Sort the fitness in ascending order and store the best solution in X_{Best}
Set the value of pl
while (iter < $iter_{max}$)
Update the selected chaotic map parameter y_{iter}
    Form two vectors of parents' IDs using (27)
    Using the chaotic y_{iter}, update the parameters α using (32)
    for each search agent X_i
        if $|ID_D - ID_M| \le pl$
            Generate a new offspring using (28)
        else
            Generate a new offspring using (29)
        end if
Calculate the quasi oppositional for all new barnacles using (30)
    Calculate the objective function.
    Sort the fitness in ascending order and update the best solution X_{Best}
    iter = iter + 1
end while
return the final best solution stored X_{Best}

Fig 9. BMO algorithm flow chart

2.6 Artificial Neural Network (ANN)

Forecasting process of artificial NN is employed to augment the wind velocity including optimal wind velocity factor. This Wind velocity factor is deemed as input, whereas probability of the available wind is deemed as network outcome. When the procedure of learning that is determined and regulated by weights, the outputs is obtained by non-linear task of the input. ANN is used to capture unpredictable events of the wind power; therefore, the method guarantees the maximal wind power usage. Here, proposed hybrid approach solution of decreased the total cost. In this manuscript, a hybrid control scheme for PQ improvement in grid connected hybrid RES such as PV energy, wind energy and Battery is proposed. The proposed method is the consolidation of Hybrid Barnacles Mating Optimization Algorithm (HBMO) and Artificial Neural Network (ANN), hence it is called HBMO-ANN method. The major intention of this work is "improve the power quality based on the grid connected and independent microgrid mode based on total harmonics and unbalanced condition". The ABMO method is taught using inputs, namely previously available immediate sources of energy. The present time's necessary load need depending on the desired reference power sources. The proposed method's simulation analysis is conducted using the provided test cases with various nonlinear load combinations.

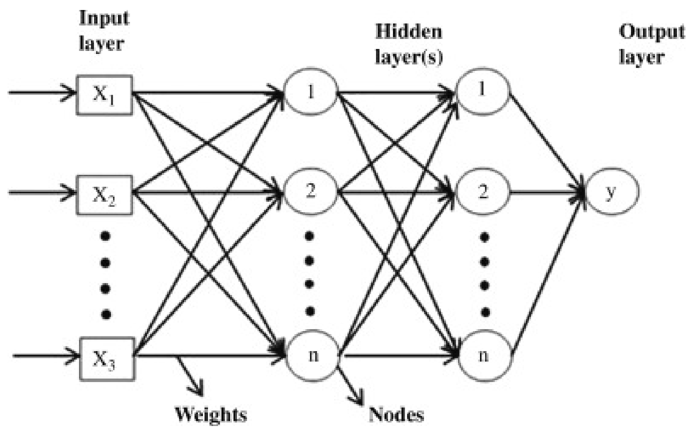


Fig 10. ANN

3 Proposed Methodology of H BMO-ANN for Power Quality Improvement

In this manuscript, a hybrid controller scheme for the PQ improvement in the grid-integrated hybrid RES viz, photovoltaic, wind energy and Battery is proposed. The proposed method is the combination of Barnacles Mating Optimization Algorithm (BMO) and the Artificial Neural Network (ANN), hence it is called HBMO-ANN control scheme. Here, the major purpose this work is "improve the power quality based on the grid connected and independent mode of micro grid based on total harmonics and unbalanced condition". The BMO method is tuned with the inputs i.e. recent instantaneous energy of the obtainable sources and the necessary demand requirement, based on the intended target power sources[11]. The HBMO-ANN control model generates the proportional integral gain parameters of the controller based on the fluctuation of loads, to give the optimum signal to control and maintains the hybrid RES energy. This Novel approach prediction is a process that assumes all kind of variables in the system parameters viz, direct current voltage, active with reactive power. Therefore, the proposed ABMO-ANN method generates the optimal control which seeks to improve the damping of power system, also maintains the line voltage by producing the compensation of reactive power. Forecasting process of artificial NN is employed to augment the wind velocity including optimal wind velocity factor. This Wind velocity factor is deemed as input, whereas probability of the available wind is deemed as network outcome. When the procedure of learning that is determined and regulated by weights, the outputs is obtained by non-linear task of the input. ANN is used to capture unpredictable events of the wind power; therefore, the method guarantees the maximal wind power usage. Here, proposed hybrid approach solution of decreased the total cost.

Table 2. Results of multi-modal benchmark functions

Function		ABC	ANN	BMO	HBMO
F1	Best	2.58E−87	2.04E−01	3.63E−14	4.72E−149
	Worst	3.04E−72	1.64E+00	1.09E−05	1.43E−124
	Mean	1.60E−73	7.05E−01	7.85E−07	5.37E−126
	Std	6.20E−73	3.65E−01	2.68E−06	2.61E−125
F2	Best	4.80E−58	7.50E−02	2.59E−03	5.18E−79
	Worst	4.81E−50	3.13E−01	4.16E−01	5.53E−67
	Mean	2.37E−51	1.81E−01	7.03E−02	2.17E−68
	Std	8.82E−51	6.57E−02	9.65E−02	1.01E−67
F3	Best	1.35E+04	3.48E+03	1.31E+01	5.45E−140
	Worst	7.34E+04	1.88E+04	8.22E+02	3.83E−110
	Mean	4.91E+04	1.19E+04	1.14E+02	2.96E−111
	Std	1.45E+04	3.68E+03	1.52E+02	9.60E−111
F4	Best	4.10E−01	8.23E+00	6.72E−01	3.65E−79
	Worst	8.78E+01	3.12E+01	4.56E+00	5.33E−59
	Mean	5.42E+01	1.93E+01	2.36E+00	2.32E−60
	Std	2.50E+01	5.90E+00	1.09E+00	9.85E−60
F5	Best	2.74E+01	8.92E+01	1.13E+01	2.68E+01
	Worst	2.87E+01	3.28E+03	1.73E+02	2.80E+01

Continued on next page

Table 2 continued

	Mean	2.81E+01	5.22E+02	5.63E+01	2.72E+01
	Std	4.25E−01	8.82E+02	4.38E+01	3.12E−01
F6	Best	8.61E−02	9.48E−02	1.59E−12	9.14E−03
	Worst	8.93E−01	2.11E+00	1.01E−04	5.81E−01
	Mean	4.24E−01	8.55E−01	3.94E−06	8.29E−02
	Std	2.15E−01	4.87E−01	1.85E−05	1.28E−01
F7	Best	5.37E−05	4.00E−02	1.04E−02	1.59E−04
	Worst	1.85E−02	1.74E−01	5.85E−02	2.80E−03
	Mean	3.82E−03	8.80E−02	2.76E−02	9.00E−04
	Std	4.85E−03	3.29E−02	1.23E−02	6.61E−04
F8	Best	−1.91E+03	−1.76E+03	−1.56E+03	−1.74E+03
	Worst	−1.63E+03	−1.32E+03	−1.04E+03	−1.64E+03
	Mean	−1.86E+03	−1.53E+03	−1.28E+03	−1.68E+03
	Std	9.89E+01	1.11E+02	1.26E+02	2.67E+01
F9	Best	0.00E+00	5.85E−01	4.18E+01	0.00E+00
	Worst	0.00E+00	8.91E+00	1.33E+02	0.00E+00
	Mean	0.00E+00	3.68E+00	7.53E+01	0.00E+00
	Std	0.00E+00	1.86E+00	2.43E+01	0.00E+00
F10	Best	8.88E−16	2.00E+01	3.79E+00	8.88E−16
	Worst	7.99E−15	2.00E+01	2.03E+01	8.88E−16
	Mean	4.44E−15	2.00E+01	1.94E+01	8.88E−16
	Std	2.29E−15	7.76E−04	2.96E+00	4.01E−31
F11	Best	0.00E+00	1.83E−02	9.29E−13	0.00E+00
	Worst	1.40E−01	1.38E−01	4.43E−02	0.00E+00
	Mean	4.66E−03	4.94E−02	1.39E−02	0.00E+00
	Std	2.55E−02	2.32E−02	1.43E−02	0.00E+00
F12	Best	4.72E−03	1.67E−05	4.84E−17	5.72E−03
	Worst	4.43E−02	1.04E−01	4.15E−01	2.13E−01
	Mean	1.39E−02	3.61E−03	2.42E−02	4.17E−02
	Std	8.54E−03	1.89E−02	8.02E−02	4.02E−02
F13	Best	2.69E−01	8.52E−02	1.10E−02	4.64E−02
	Worst	1.25E+00	8.96E−01	3.61E+00	2.97E+00
	Mean	7.56E−01	2.58E−01	9.06E−01	5.49E−01
	Std	2.50E−01	1.94E−01	1.11E+00	6.74E−01
F14	Best	9.98E−01	9.98E−01	9.98E−01	9.98E−01
	Worst	1.08E+01	9.98E−01	1.64E+01	7.87E+00
	Mean	3.06E+00	9.98E−01	5.22E+00	2.45E+00
	Std	3.58E+00	4.52E−16	3.74E+00	1.95E+00
F15	Best	3.09E−04	3.94E−04	3.07E−04	3.08E−04
	Worst	2.81E−03	2.07E−02	2.04E−02	2.04E−02
	Mean	8.21E−04	5.76E−03	2.45E−03	1.97E−03
	Std	6.88E−04	7.25E−03	6.08E−03	5.00E−03
F16	Best	−1.03E+00	−1.03E+00	−1.03E+00	−1.03E+00
	Worst	−1.03E+00	−1.03E+00	−1.03E+00	−1.03E+00
	Mean	−1.03E+00	−1.03E+00	−1.03E+00	−1.03E+00
	Std	6.78E−16	6.78E−16	6.78E−16	6.78E−16
F17	Best	3.98E−01	3.98E−01	3.98E−01	3.98E−01
	Worst	3.98E−01	3.98E−01	3.98E−01	3.98E−01
	Mean	3.98E−01	3.98E−01	3.98E−01	3.98E−01
	Std	1.22E−05	3.65E−06	1.69E−16	1.69E−16
F18	Best	3.00E+00	3.00E+00	3.00E+00	3.00E+00
	Worst	3.00E+00	3.00E+01	3.00E+00	3.00E+00
	Mean	3.00E+00	3.90E+00	3.00E+00	3.00E+00
	Std	1.72E−04	4.93E+00	0.00E+00	0.00E+00
F19	Best	−3.00E−01	−3.00E−01	−3.00E−01	−3.00E−01
	Worst	−3.00E−01	−3.00E−01	−3.00E−01	−3.00E−01

Continued on next page

Table 2 continued

	Mean	−3.00E−01	−3.00E−01	−3.00E−01	−3.00E−01
	Std	1.13E−16	1.13E−16	1.13E−16	1.13E−16
F20	Best	−3.32E+00 −	−3.32E+00 −	−3.32E+00 −	−3.32E+00 −
	Worst	5.61E−02	3.20E+00	3.20E+00	3.09E+00
	Mean	−2.61E+00	−3.28E+00	−3.27E+00	−3.26E+00
	Std	1.03E+00	5.83E−02	6.03E−02	8.17E−02
F21	Best	−1.02E+01	−1.02E+01	−1.02E+01	−1.02E+01
	Worst	−8.82E−01	−2.63E+00	−2.63E+00	−2.63E+00
	Mean	−8.13E+00	−5.00E+00	−5.98E+00	−5.84E+00
	Std	2.78E+00	3.46E+00	3.55E+00	2.30E+00
F22	Best	−1.04E+01	−1.04E+01	−1.04E+01	−1.04E+01
	Worst	−2.76E+00	−2.75E+00	−1.84E+00	−2.75E+00
	Mean	−6.99E+00	−6.63E+00	−6.74E+00	−7.10E+00
	Std	3.07E+00	3.66E+00	3.78E+00	3.01E+00
F23	Best	−1.05E+01	−1.05E+01	−1.05E+01	−1.05E+01
	Worst	−2.80E+00	−2.42E+00	−2.43E+00	−2.43E+00
	Mean	−8.45E+00	−6.06E+00	−7.49E+00	−7.06E+00
	Std	2.77E+00	3.75E+00	3.61E+00	3.41E+00

4 Result and Discussion

In this manuscript, a hybrid control scheme for PQ improvement in grid connected hybrid RES such as PV energy, wind energy and Battery is proposed. The proposed method is the consolidation of Hybrid Barnacles Mating Optimization Algorithm (HBMO) and Artificial Neural Network (ANN), hence it is called HBMO-ANN method. The major intention of this work is "improve the power quality based on the grid connected and independent microgrid mode based on total harmonics and unbalanced condition". The HBMO method is taught using inputs, namely previously available immediate sources of energy. The present time's necessary load need depending on the desired reference power sources. The proposed method's simulation analysis is conducted using the provided test cases with various nonlinear load combinations.

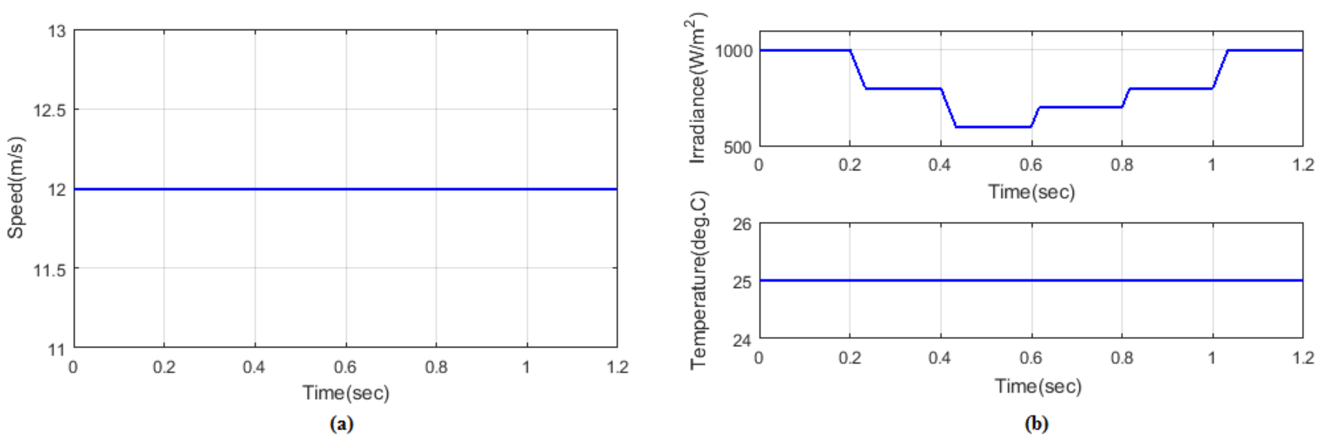


Fig 11. PV analysis of (a) Speed (b) irradiance and temperature

Figure 12 shows the individual power of existing method for grid. In subplot (a) the existing ABC is presented. Here the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w. The grid flows from 0 to 4500w and the load flows from 0 to 14000w. In subplot (b) the existing ANN is presented. Here the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w. In subplot (c) the existing BMO is presented. Here the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w.

Figure 13 shows the individual power of existing method for islanding grid. In subplot (a) the existing ABC is presented. Here the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w. The grid flows from 0 to 4500w and the load flows from 0 to 1400w. In subplot (b) the existing ANN is presented. Here

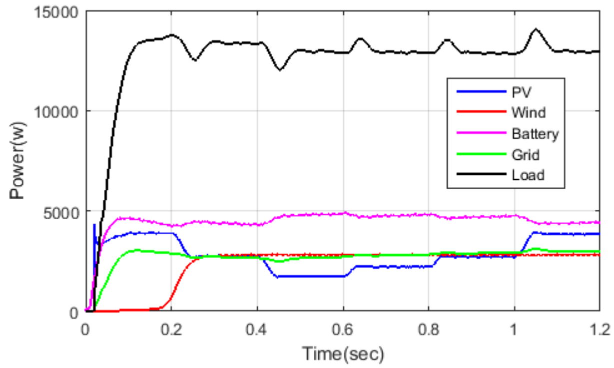


Fig 12. Power of proposed method for grid

the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w. In subplot (c) the existing BMO is presented. Here the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w.

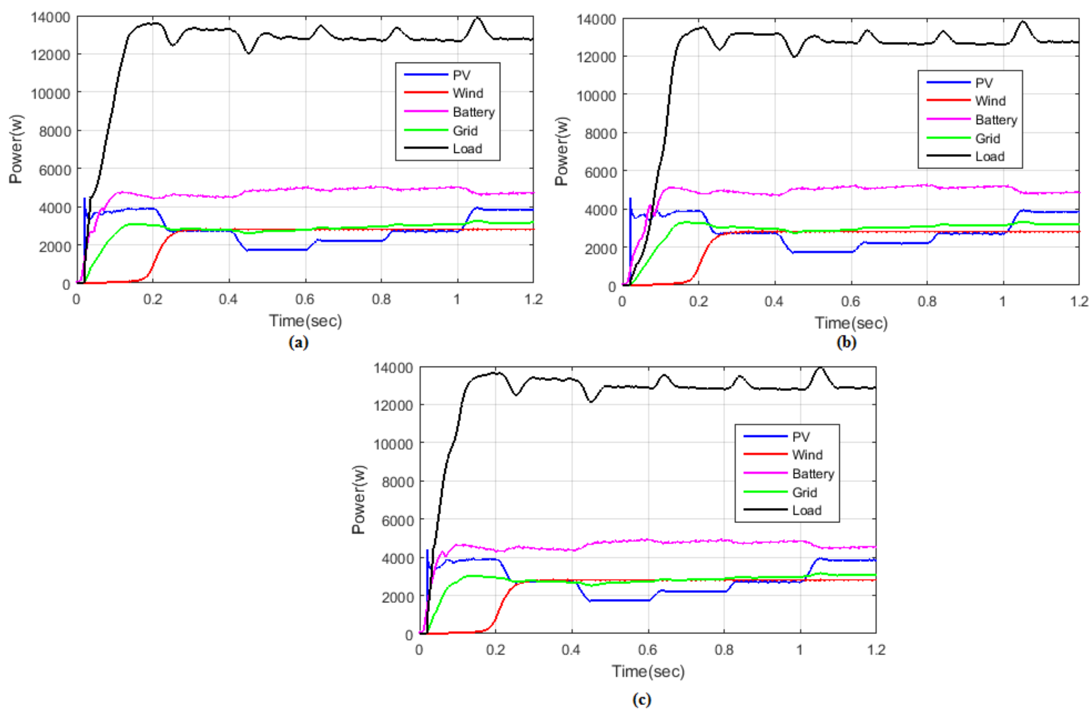


Fig 13. Individual Power of Existing method for grid (a) ABC (b) ANN (c) BMO

Figure 14 depicts the wind analysis of speed, irradiance, temperature. In subplot (a), the PV analysis of wind is presented. In subplot (b) the wind analysis of temperature and irradiance is presented. The irradiance here varies between 1000 and 500Q/m^2, but the temperature stays unchanged at 25C.

Figure 15 shows the Individual power of proposed method for grid based on PV, Wind, Battery, Grid and load. Here the PV flows from 0 to 4900w and it increased up to 5000. The wind flows from 0 to 4000w. The battery flows from 0 to 4999w. The grid flows from 0 to 4500w and the load flows from 0 to 1400w

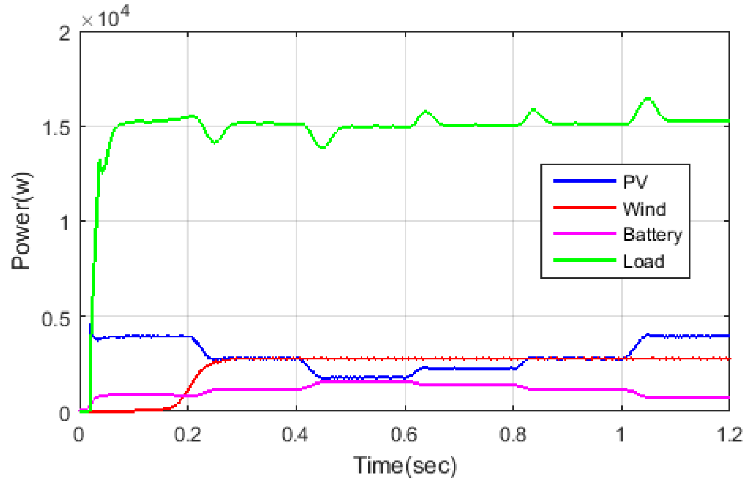


Fig 14. Power of proposed method for islanding grid

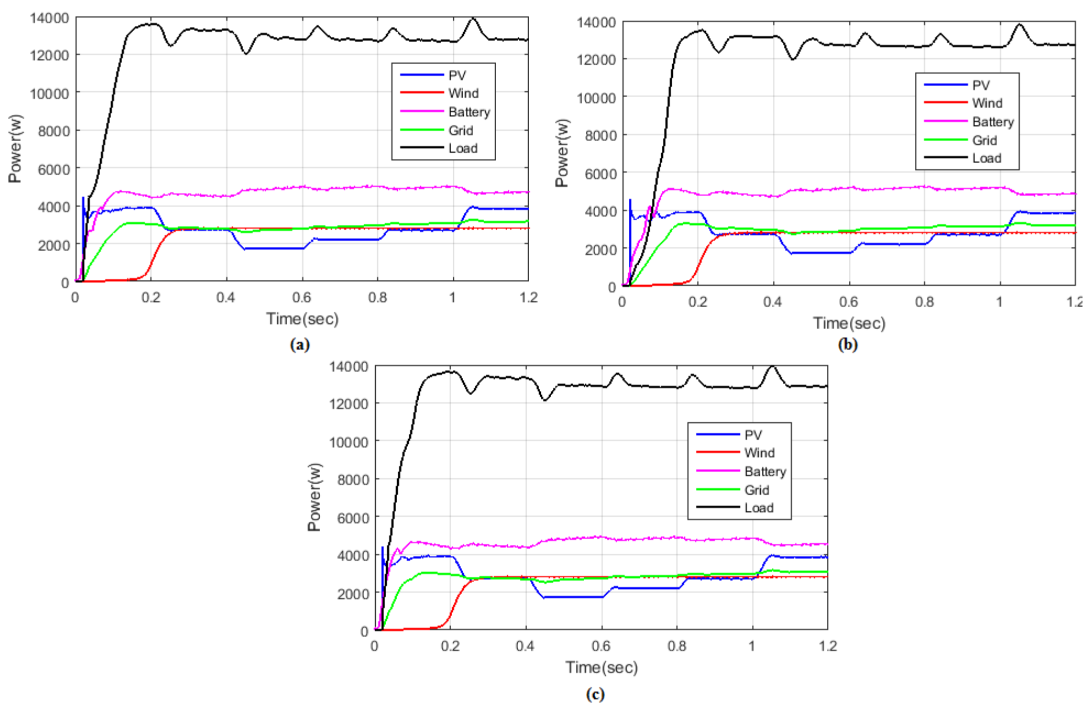


Fig 15. Individual Power of Existing method for islanding grid (a) ABC (b) ANN (c) BMO

Table 3. Comparison of Various algorithms for PQI in grid and islanded mode

Parameters	**Grid connected mode**			**Islanded mode**		
	V_b (Voltage Mag.at PCC)	THD_v	THD_i	V_b	THD_v	THD_i
Normal	0.96	4.50%	10%	0.94	5.60%	12%
ABC	0.96	4.00%	9.30%	0.95	4.27%	10.11%
ANN	0.97	3.26%	7.13%	0.96	3.15%	8.41%
BMO	0.98	2.15%	4.30%	0.97	2.73%	5.13%
HBMO & ANN	0.99	1.20%	3.60%	0.98	1.40%	3.80%

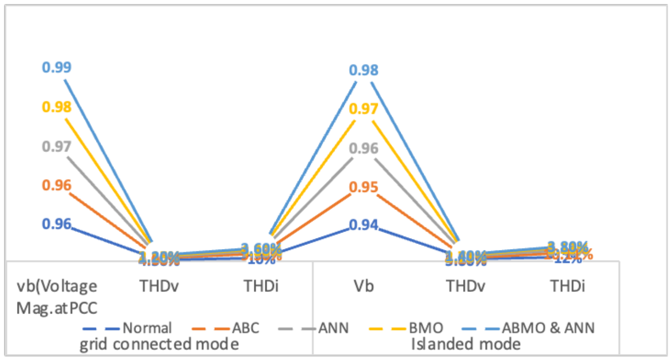


Fig 16. Comparative study of the Algorithms with voltage unbalance and Harmonic distortion

5 Conclusion

This study presents the Grid connected mode PI control with total harmonics of Voltage is 4.50% and Total harmonics distortion of current is 10%. At Islanded mode the PI control total harmonics of Voltage is 5.6% And Total harmonics distortion of current is 12%. And with the voltage magnitude at the bus of point of common coupling (PCC) is 0.96 and 0.94 respectively. The response time of HBMO_ANN control is much better than other existing PI control algorithms. Both the grid current total harmonic distortion (THD) and inverter injected current THD are decreased to 3.60% and 3.80%, respectively, in both the mode of operations. Here, HBMO_ANN based control illustrates enhanced performance in terms of inverter-injected current quality.

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