Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 15, Issue. 1, No.11: 2024
ISSN : **1906-9685**

Hybrid Wind/PV/Battery Energy Management-Based Three Level Converter with FOPID Control Strategy

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Abstract: *This paper deals with the study of an electrical energy production system made up of three sources of energy: photovoltaic energy, wind and a battery. The optimization of this hybrid production system is ensured by the control of each part. The hybrid system chain also contains a multilevel inverter that improves the quality of energy injected into the alternating load and consequently reduces the harmonic rate. Fractional Order PID (FOPID) controller is used to achieve maximum power to a DC bus voltage. In order to optimize the power flow in the different parts of the production line, an energy management algorithm is developed in order to mitigate the fluctuations of the load. The considered system was implemented in the Matlab/Simulink, the results show the effectiveness of the proposed method and can be realized with simulation setup.*

Keywords: *Wind, Photovoltaic PV, Battery, Hybrid System, MPPT tracking, Three Level Inverter, Fractional Order PID (FOPID) controller.*

I.INTRODUCTION

The production of electrical energy in the world generates various types of pollution. Thermal power plants (coal, oil) are responsible for atmospheric emissions linked to the combustion of fossil fuels. On the other hand, nuclear power plants, whose development intensified following the oil crisis, have not had a negative impact on air quality. On the other hand, they produce radioactive waste which causes major problems in terms of storage, processing, and transport. Today, the fear of using only one energy source with all its risks, and the opening of the electricity production market are all factors that give renewable energies (hydraulic, wind, solar, biomass, etc.) an important place in electricity production [1], [2]. The demand for energy by consumers is generally not evenly distributed over time and problems of the phasing of energy produced versus energy consumed arise. The stability of the grid depends on the balance between production and consumption [3]. The increase in the penetration rate of renewable energies will therefore be conditioned by their participation in these different services, which will be favored by the association with these clean energy sources, of electrical energy storage systems [4]. Storage is therefore the key to the penetration of these energies in the electricity grid. Not only does it provide a technical solution for the grid operator to ensure a real-time balance of production and consumption, but it also enables the best possible use of renewable resources by avoiding load shedding in the event of overproduction. Combined with local renewable generation, decentralized storage would also have the advantage of improving the robustness of the electricity network by allowing islanding of the area supplied by this resource. Also, a well-placed energy storage system (ESS) increases the quality of the power supplied by providing better control of frequency and voltage and reduces the impact of its variability by adding value to the current supplied, especially if the electricity is delivered during peak periods [5], [6]. The integration of renewable energies together with the energy storage system in a standalone micro grid is an emerging research area. Generally, it is preferred to integrate different renewable energies such as tidal, wind, and PV to yields a positive impact on the maximum capacity of the energy storage system. Usually, ESS is constituted by a combination of a battery and supercapacitors, which helps extend battery life-time and offers a fast system response to compensate the transients [7]. However, loads are necessary when all (energy sources and battery storage systems (BSS)) are connected; thus, the AC grid is used instead of supercapacitors [8]. A micro grid is classified into DC, AC, or a combination of both types. Compared with AC microgrid, DC microgrid shows several benefits such as fewer parameters to control, facilitate integration, and simple structure. On the other hand, AC type needs more information like the synchronization of the frequency and reactive power, which makes the control design process a challenging task. Moreover, a DC micro grid offers the possibility to work in different modes like AC microgrid, standalone, or integrated with the AC microgrid [9], [10]. Due to the latest development in power electronics, the autonomous DC microgrid can work at its maximum performance. However, because of the renewable energy sources stochastic nature, the smooth operation and continuous power transmission to the loads need a supplementary energy management unit. Numerous research works on the energy management control dedicated to AC microgrids can be found in the literature, but given the important differences between the AC and DC microgrid dynamics, these control strategies cannot be adopted for DC microgrids. In fact, in the standard design of the DC microgrid, the load converters and the energy sources are parallelly connected where the energy is consumed or supplied through the DC-link. Thus, the control of the DC-link voltage is needed for an efficient and stable operation of the DC microgrid [11], [12]. Several control strategies have appeared in the literature to address the issues of the DC-link voltage. In [13], a review of the recent trends and development in hybrid micro grid topology with energy resource planning and control is presented. In [14], a combined fuzzy controller and voltage control are proposed to regulate the DC voltage. In [15], a fuzzy logic control strategy with reduced rules is investigated. In [16], a dual proportional-integral controller is adopted. However, the aforementioned control strategies are linear and can regulate the DC-link in a small operating interval. Thus, to overcome this restriction, nonlinear controls have been investigated in the literature. in [17], an adaptive droop controller algorithm is proposed. Energy management-based optimal control is investigated in [18] for multiple energy storage system in a microgrid. In [19], robust H∞ control strategy is developed. Robust sliding mode strategy is proposed in [20]. In [21], an adaptive backstepping control method is designed. A Lyapunov-based strategy is presented in [22]. Feedback linearization control is discussed in [23]. A hybrid combined backstepping and sliding mode controller is investigated in [24]. However, the previous proposed nonlinear controls show limitations in performances in the case of droop control strategy and optimal energy management has given the multiple integrated energy storage system, poor stability for the H∞ method, chattering issues concerning the sliding mode. Also, the major part of these controls highly depends on fixed gains which are very sensitive to parameter uncertainties and external disturbances. Finally, the last part represents the energy management unit. In the same context, in the present work, a new fractional order PID controller is proposed combined with a fuzzy logic method to address the problems faced by the conventional integer controls in hybrid energy management. Fractional-order controllers offer additional advantages over integer order controls such as robust behavior to oscillations and the measurement noise and high degree of freedom. The proposed new controller is integrated with an energy management unit for a DC-microgrid integrated with several stochastic sources and essential DC loads illustrated by Figure 1. The proposed Fractional Order PID (FOPID) controller will be used as a low-level controller, when the energy management unit serves as high-level controller which generates appropriate references for the FOPID and monitors the generated and consumed power. This paper addresses the controlling the load-side converters to extract the maximum power from the renewable energy sources (wind and PV) using the proposed FOPID and improve the quality of power at DC microgrid

II. LITERATURE SURVEY

[1] H. T. Dinh, J. Yun, D. M. Kim, K. Lee, and D. Kim, ''A home energy management system with renewable energy and energy storage utilizing main grid and electricity selling,'' IEEE Access, vol. 8, pp. 49436–49450, 2020.

With the development of new technologies in the field of renewable energy and batteries, increasing number of houses have been equipped with renewable energy sources (RES) and energy storage systems (ESS) to reduce home energy cost. These houses usually have home energy management systems (HEMS) to control and schedule every electrical device. Various studies have been conducted on HEMS and optimization algorithms for energy cost and peak-to-average ratio (PAR) reduction. However, none of papers give a sufficient study on the utilization of main grid's electricity and selling electricity. In this paper, firstly, we propose a new HEMS architecture with RES and ESS where we take utilization of the electricity of the main grid and electricity selling into account. With the proposed HEMS, we build general mathematical formulas for energy cost and PAR during a day. We then optimize these formulas using both the particle swarm optimization (PSO) and the binary particle swarm optimization (BPSO). Results clearly show that, with our HEMS system, RES and ESS can help to drop home energy cost significantly to 19.7%, compared with the results of previous works. By increasing charge/discharge rate of ESS, energy cost can be decreased by 4.3% for 0.6 kW and 8.5% for 0.9 kW. Moreover, by using multi-objective optimization, our system can achieve better PAR with an acceptable energy cos

[2] C. Byers and A. Botterud, ''Additional capacity value from synergy of variable renewable energy and energy storage,'' IEEE Trans. Sustain. Energy, vol. 11, no. 2, pp. 1106–1109, Apr. 2020.

Current capacity markets often consider capacity credits from each resource independently, irrespective of the portfolio of resources, potentially overvaluing or undervaluing the capacity contribution of variable renewable energy (VRE) and energy storage (ES) in the grid. We propose a method for calculating the standalone and integrated capacity value of an added VRE resource with existing ES resources. The difference between the integrated and standalone value is the portfolio effect. This is the additional capacity value gained by the synergy of VRE and the existing fleet. Using chronological dispatch simulations and two different reliability metrics to estimate firm capacity, we demonstrate on a small test system that the portfolio effect can be substantial.

[3] M. Rizwan, L. Hong, W. Muhammad, S. W. Azeem, and Y. Li, ''Hybrid Harris Hawks optimizer for integration of renewable energy sources considering stochastic behavior of energy sources,'' Int. Trans. Elect. Energy Syst., vol. 31, no. 2, 2021, Art. no. e12694, doi: 10.1002/2050- 7038.12694.

Renewable energy sources powered distributed generation (RES-DG) is getting more indispensable to encounter the considerable increase in demand for electric energy owing to its techno-economic benefits and eco-friendly nature. An economic solution to this demand can only be obtained with the optimal placement and sizing of RES-DGs. The optimal siting and sizing of RES-DG, such as Photovoltaic (PV) and Wind Turbine (WT) is still a hot topic due to the uncertainties in solar irradiance (SI) and wind speed (WS). The main objective of this research paper is to develop a RES-DG siting and sizing strategy for the discrete, nonlinear siting and sizing pattern of RES-DGs using a novel hybrid Harris' Hawk optimizer (HHHO), considering the stochastic nature of SI and WS. The Weibull and Beta probability density functions (PDFs) are utilized for modeling the stochastic nature of WS and SI, respectively. The optimization of the multiobjective function comprises active power loss reduction, enhancement in voltage profile, and improvement in voltage stability index (VSI). Different scenarios of single and multiple RES-DGs and capacitor banks (CB) are examined to validate the efficiency of the proposed novel HHHO based RES-DGs siting and sizing strategy. The results show a considerable reduction in power loss, enhancement in the system voltage profile, and improvement in VSI. Evaluation of results by comparing withstate-of-art hybrid algorithms shows that the proposed solution using HHHO algorithm is globally optimum.

[4] Y. Sun, Z. Zhao, M. Yang, D. Jia, W. Pei, and B. Xu, ''Overview of energy storage in renewable energy power fluctuation mitigation,'' CSEE J. Power Energy Syst., vol. 6, no. 1, pp. 160–173, 2020.

The integration of renewable energy, such as PV and wind power, has exerted great impacts on the power system with its rapid development. If the corresponding energy storage system is configured, the power system could be able to hold a higher proportion of renewable energy. Focusing on energy storage application for the output fluctuation mitigation of renewable energy, this paper first analyses the reason for renewable energy power fluctuation mitigation from the four aspects of frequency, unit ramp, low frequency oscillation and cascading failure. In addition, the fluctuation rate standard of grid-connected renewable energy, the energy storage type and the mitigation topology are introduced. Then a summary and analysis on mitigation strategy and hybrid energy storage allocation strategy are presented. Finally, the demonstration application and development trend of energy storage are analyzed to provide reference for the promotion of energy storage in renewable energy.

[5] T. Salameh, M. A. Abdelkareem, A. G. Olabi, E. T. Sayed, M. Al-Chaderchi, and H. Rezk, ''Integrated standalone hybrid solar PV, fuel cell and diesel generator power system for battery or supercapacitor storage systems in khorfakkan, united arab emirates,'' Int. J. Hydrogen Energy, vol. 46, no. 8, pp. 6014–6027, Jan. 2021.

Renewable energy resources play a very important rule these days to assist the conventional energy systems for doing its function in the UAE due to high greenhouse gas (GHG) emissions and energy demand. In this paper, the analysis and performance of integrated standalone hybrid solar PV, fuel cell and diesel generator power system with battery energy storage system (BESS) or supercapacitor energy storage system (SCESS) in Khorfakkan city, Sharjah were presented. HOMER Pro software was used to model and simulate the hybrid energy system (HES) based on the daily energy consumption for Khorfakkan city. The simulation results show that using SCESS as an energy storage system will help the performance of HES based on the Levelized cost of energy (LCOE) and greenhouse gas (GHG) emissions. The HES with SCESS has renewable fraction (68.1%) and 0.346 $/kWh LCOE. The HES meets the annual AC primary load of the city (13.6 GWh) with negligible electricity excess and with an unmet electrical load of 1.38%. The reduction in GHG emissions for HES with SCESS was 83.2%, equivalent to saving 814,428 gallons of diesel.

III. PROPOSED SYSTEM

The topology presents a combined hybrid energy system integrated AC-load, where three main parts can be distinguished: the hybrid energy sources constituted by the wind energy, solar energy, and the BSS connected to the DC-link through their respective converters. The second part represents the loads assumed to be a priority which in the case of a smart university may include laboratory experimentation benches, fans, and lighting. A maximum power point tracking algorithm is used on solar (PV) conversion systems to force them to operate at maximum power. The energy management unit computes the total consumed and produced energy to order to select the adequate control modes. Thus, the generalized energy management controller structure is illustrated in Fig.1

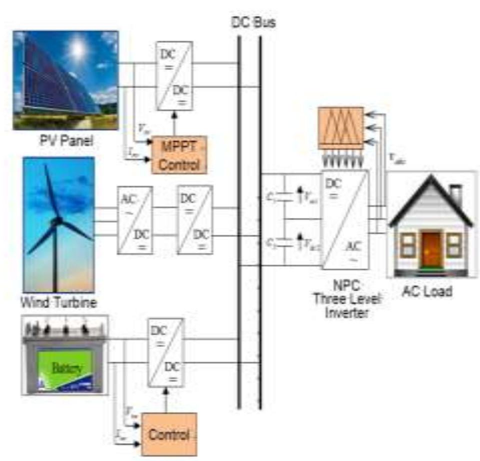

Fig 1 Proposed configuration of hybrid system with battery

IV.MATHEMETICAL MODELLING

A) WIND SYSTEM MODEL

The mathematical model of the wind power that can be transformed by the turbine is given by:

$$P_m = \frac{1}{2}\,\rho Cp(\beta,\lambda)Av3 \qquad (1)$$

$$T_m = \frac{P_m}{w_t} \qquad (2)$$

$$C_p(\beta,\lambda) = \frac{1}{2}\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{-\left(\frac{21}{\lambda_i}\right)} \qquad (3)$$

$$\lambda_i^{-1} = (\lambda + 0.88\beta)^{-1} - 0.0365(1+\beta^3)^{-1} \; (4)$$

$$\lambda = \frac{\omega_t R}{v}, \qquad (5)$$

where, v denotes the wind speed, β represents the pitch angle, ωt denotes the turbine speed, R represents the blades radius, Cp denotes the power coefficient, λ denotes the tip-speed ratio, ρ denotes the water density, and A represents the area of the blades. The wind conversion system is based on a permanent magnet synchronous generator (PSMG) which is expressed as,

$$vdq \;=\; Rdqidq \;+\; Ldq\dot{i}dq \;+\; \psi dqp\omega m \; (6)$$

$$J\,\dot{\omega}m = Tm - Te - ffv\omega m \qquad (7)$$

$$T_e = \frac{2}{3}p\psi_{dq}^T i_{dq} \qquad (8)$$

where, $i_{dq} = \begin{bmatrix} i_d \\ i_q \end{bmatrix}$ represents the stator current vector, $T_e$represents the electromagnetic torque, f_{fv}represents the viscous friction coefficient,$L_{dq} = \begin{bmatrix} L_d & 0 \\ 0 & L_q \end{bmatrix}$ represents dq inductances matrix, J is the moment of inertia, $\psi_{dq} = \begin{bmatrix} \psi_f \\ 0 \end{bmatrix}$ represents the flux linkages vector, $v_{dq} = \begin{bmatrix} v_d \\ v_q \end{bmatrix}$represents voltage stator vector, and $R_{dq} = \begin{bmatrix} R_d & 0 \\ 0 & R_q \end{bmatrix}$represents the stator resistance matrix. To design the proposed control method, the model of the SCCs needs to be expressed. Thus, the model of the wind source converter (see Figure 3.1) is given as

$$\frac{dV_\omega}{dt} = \frac{I_\omega}{C_\omega} - \frac{I_{L\omega}}{C_\omega} \qquad (9)$$

$$\frac{V_\omega}{L_\omega} = \frac{dI_\omega}{dt} + (1-U_1)\frac{V_{dc}}{L_\omega} - D_1 \qquad (10)$$

$$\frac{dV_{dc}}{dt} = (1-U_1)\,\frac{I_{L\omega}}{C_{dc}} - \frac{I_{O\omega}}{C_{dc}} + D_2 \qquad (11)$$

where, I_ω denotes the wind current rectified, $L\omega$ denotes the inductance, $I_{L\omega}$ denotes the current of the inductor, V_ω denotes the voltage input rectified, U1 denotes the control signal, V_{dc} denotes the link voltage, D_1 and D_2 denotes dynamics uncertainty in the energy stage parameters.

B) SOLAR POWER SYSTEM MODEL

A boost converter is a step up DC/DC converter which increases the solar voltage to a desired output voltage as required by load. The configuration is shown in Figure.2 , which consists of a DC input voltage Vin , inductor L, switch S, diode D1, capacitor C for filter, and load resistance R. When the switch S is ON the boost inductor stores the energy fed from the input voltage source and during this time the load current is maintain by the charged capacitor so that the load current should be continuous. When the switch S is OFF the input voltage and the stored inductor voltage will appear across the load hence the load voltage is increased. Hence, the load voltage is depends upon weather switch S in ON or OFF and this is depends upon the duty ratio D.

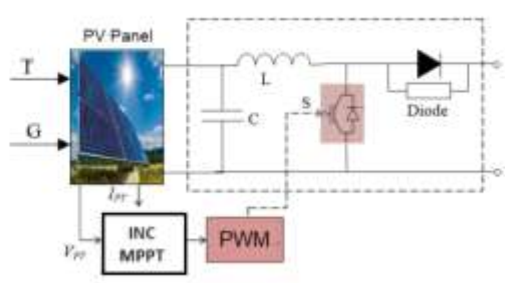

Fig.2 Solar energy system with controller.

The solar panel efficiency is increased by the use MPPT technique. The MPPT is the application of maximum power transfer theorem which says that the load will receive maximum power when the source impedance is equal to load impedance. The MPPT is a device that extracts maximum power from the solar cell and changes the duty ratio of DC/DC converter in order to match the load impedance to the source. For controlling the DC/DC converter INC MPPT is proposed.The INC MPPT flow chart is shown in in Fig.3

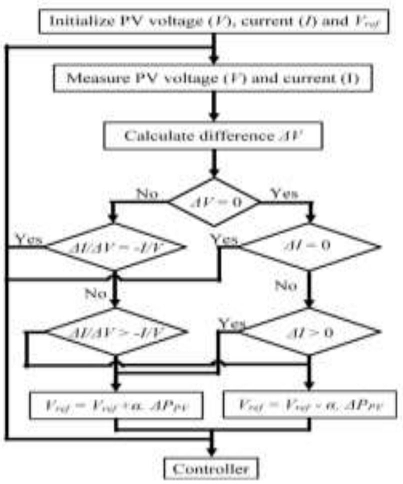

Fig.3 MPPT algorithm of the solar energy system.

C)BATTERY SYSTEM MODEL

In this application, a standard battery is connected to the DC-link through a bidirectional DC-DC back-boost converter connected at the DC-link of the microgrid (see Figure.4). The role of this converter is to maintain the DC-link voltage constant despite the power changes in the sources and the load. The DC-link voltage is regulated at it references to compute the reference current of the battery and then design the voltage controller through the proposed strategy as shown in Fig.4

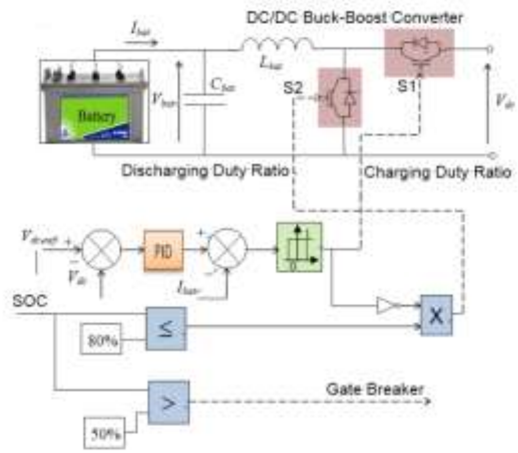

Fig.4 Battery storage system with controller.

The Battery State of Charge (SOC) model is modelled as described below,

$$SOC = 100\left(1 + \frac{\int I_{batt}dt}{Q}\right) \qquad (12)$$

The SOC, the amount of electricity stored during the charge, is an important parameter to be controlled. The battery SOC must detect by the proposed supervisory system to make decisions according to its status and the required power. In a battery, the ampere-hours stored during a time t corresponds to a nominal capacity Q and a charging current I_{batt} . The battery charge-discharge depends on the available power, the demand and the SOC. The energy constraints of the battery are determined based on the SOC limits:

$$SOC_{min} \le SOC \le SOC_{max} \qquad (13)$$

where, SOC_{min} and SOC_{max} are the minimum and the maximum allowable states for the battery safety. The model of the BSS converter is given as:

$$\frac{V_b}{L_b} = \frac{dI_{Lb}}{dt} + U_3\frac{V_{dc}}{L_p} - D_5 \qquad (14)$$

$$\frac{dV_{dc}}{dt} = U_3\frac{I_b}{C_{dc}} + \frac{I_{Ob}}{C_{dc}} - D_6 \qquad (15)$$

where, I_b denotes the current of the battery, V_b denotes the voltage of the battery, U_3 denotes the controller signal, D_5 and D_6 denotes dynamics uncertainty in the energy stage parameters.

D) THREE-LEVEL INVERTER MODELING

A three-level inverter differs from a conventional two-level inverter in that it is capable of producing three different levels of output phase voltage. The structure of a three-level neutral point clamped inverter is shown in Figure.5 When switches 1 and 2 are on the output is connected to the positive supply rail. When switches 3 and 4 are on, the output is connected to the negative supply rail. When switches 2 and 3 are on, the output is connected to the supply neutral point via one of the two clamping diodes [12, 13]. The functions $Fkm\ b$ of connection are given by:

$$\begin{cases} F_{k1}^{b} = F_{k1}.\mathrm{F}_{k2} \\ F_{k0}^{b} = F_{k3}.\mathrm{F}_{k4} \end{cases} \quad (16)$$

where, m =1 : the upper half arm and m = 0 : the lower half arm. The phase voltage VAO, VBO, VCO can be written as:

$$\begin{cases} V_{AO} = F_{11}^{b} V_{c1} - F_{10}^{b} V_{c2} \\ V_{BO} = F_{21}^{b} V_{c1} - F_{20}^{b} V_{c2} \\ V_{CO} = F_{31}^{b} V_{c1} - F_{30}^{b} V_{c2} \end{cases} \quad (17)$$

Simple output voltages are written as:

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \left\{ \begin{bmatrix} F_{11}^{b} \\ F_{21}^{b} \\ F_{31}^{b} \end{bmatrix} V_{c1} - \begin{bmatrix} F_{10}^{b} \\ F_{20}^{b} \\ F_{30}^{b} \end{bmatrix} V_{c2} \right\} \quad (18)$$

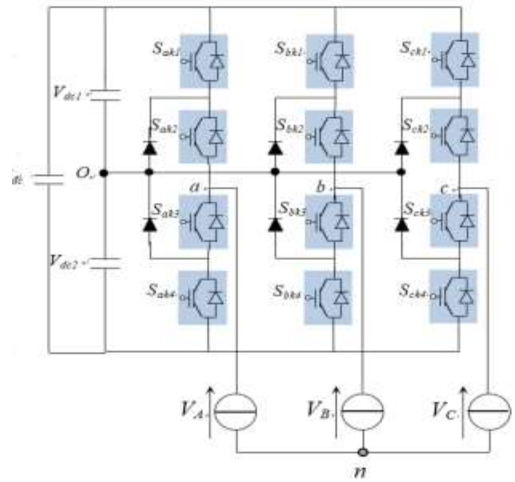

Figure.5 Three-level inverter

E) PROPOSED FOPID CONTROLLER

PID controllers are frequently employed in industrial control systems as a universal feedback control loop method. Corrective actions are generated and then produced by the PID controller in order to fix any discrepancy between a consistency process variable and the desired set point.

The following is the transfer function for a PID controller of integer order:

$$G_c(S) = K_p + K_s s^{-1} + K_d s \quad (19)$$

An integral (Ki) and a derivative (Kd) time constant are used in the PID controller design. These three parameters make up the PID controller algorithm. Error response is governed by a combination of Relative gain, the sum of recent errors, and the rate of error change, all of which are determined by the Integral. When these three acts are summed up, a control element like a control valve or a warming element can be employed to govern a process. Closed loop control systems using the PID controller can be seen in Figure.6

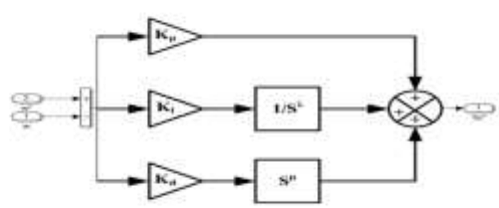

Fig.6 FOPID controller-based closed-loop process control system.

F) POWER MANAGEMENT

The proposed chart of the power management system is described in Figure.7, and it takes into consideration the following steps: Step 1: define the different powers involved in our hybrid system, Step 2: If the power supplied is greater than the requested power, in this case the excess power will be stored in the battery, Step 3: If the requested power is greater than that generated, the following two cases are distinguish: a) If the state of charge SOC is greater than 50 %, the storage battery devices are switched on. b) In the opposite case, the battery stops working, whic
h forces the delisting.

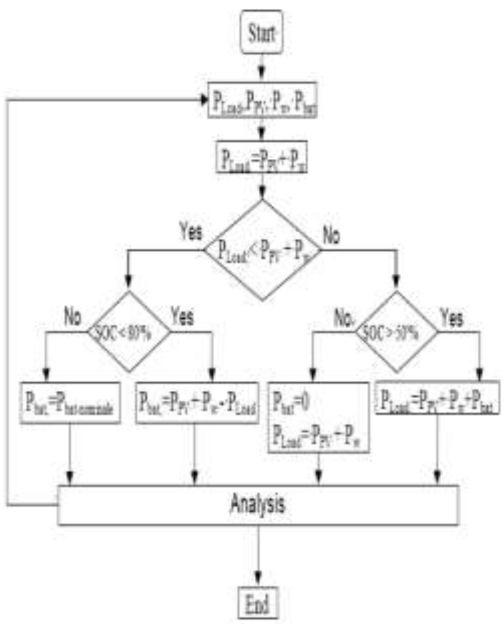

Figure.7Flow chart of the supervisory controller

V. SIMULATION RESULTS

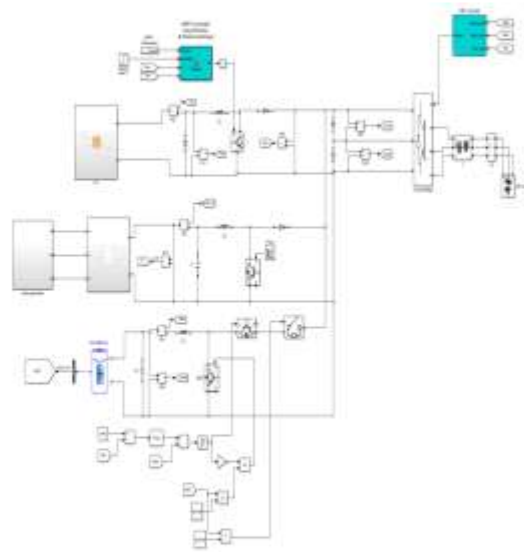

Fig.8 MATLAB/SIMULINK circuit diagram of the system

A) EXISTING RESULTS

In Figures 9, 10 and 14, the active power, current, and voltage on the load are shown. The increase of the loads can be seen clearly. First a 7 kW, then a 14 kW, then back to 7 kW, and increases to 10 kW and finally a 7 kW load were added to the system. The THD of load current is shown in Figure.20

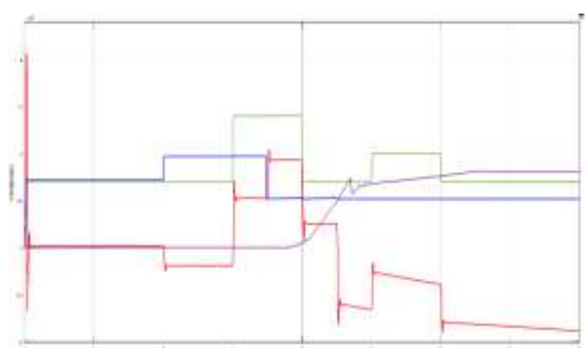

Figure.9 Power generation of the hybrid system under varying AC load

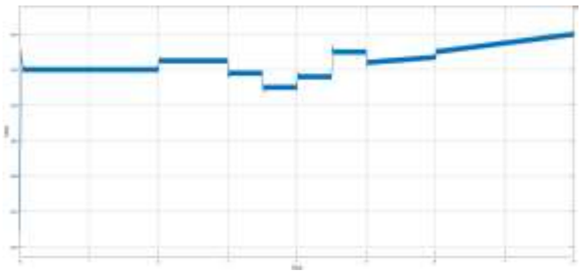

Figure.10 Output voltage battery

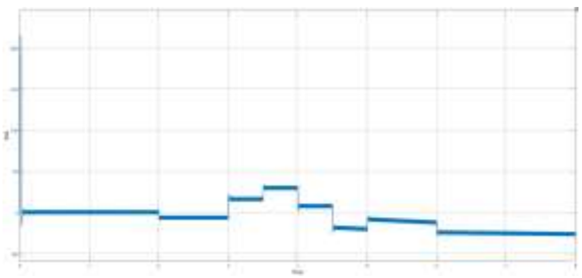

Figure.11 Output current battery

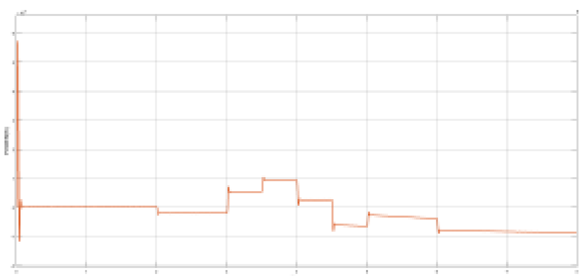

Figure.12 Power battery

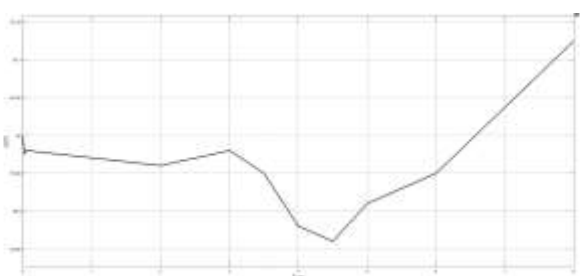

Figure.13 Global state of charge of battery

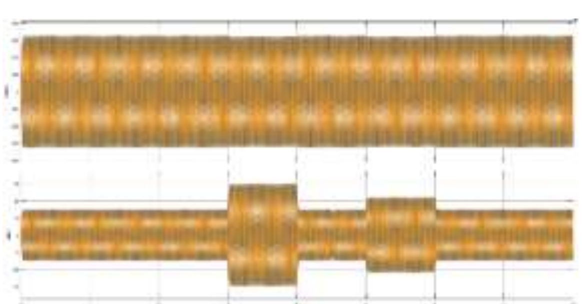

Figure.14 Output voltage and Output current for inverter

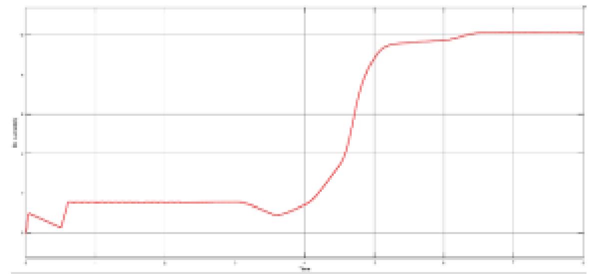

Figure.15 DC output wind current

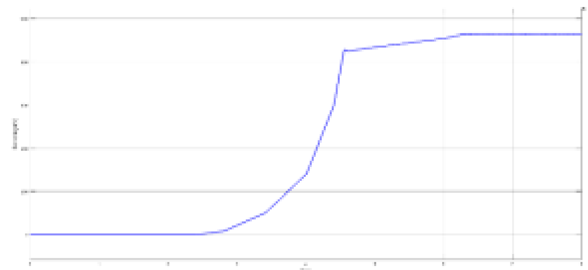

Figure.16 DC output wind voltage

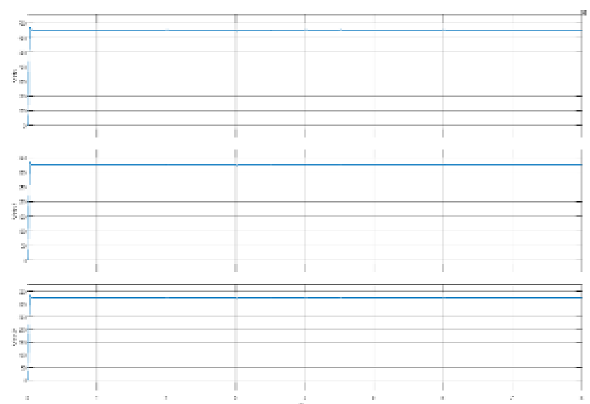

Figure.17 DC bus voltage

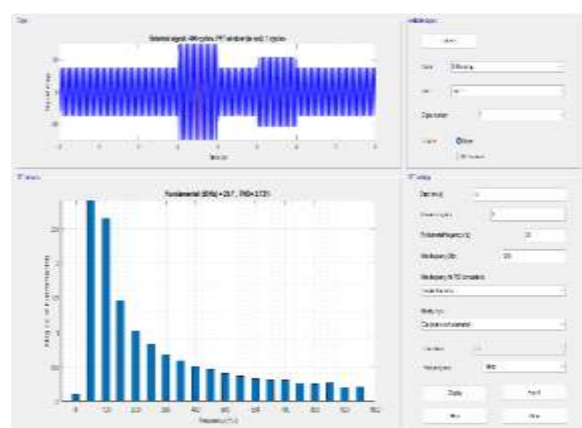

Fig.18 THD% Inverter Output current

B) EXTENSION RESULTS

In Figures 19, 20 the active power, current on the load are shown. The increase of the loads can be seen clearly. First a 7 kW, then a 14 kW, then back to 7 kW, and increases to 10 kW and finally a 7 kW load were added to the system. As a result, a total load of 45 kW is supplied. with changing power, the DC link voltage Vdc is well kept constant at the specified value (640V) which constitutes an important advantage and proves the effectiveness of the proposed schema. It has allowed us to equalize the different input DC link voltages of the multilevel inverter. The THD of load current is shown in Figure.25

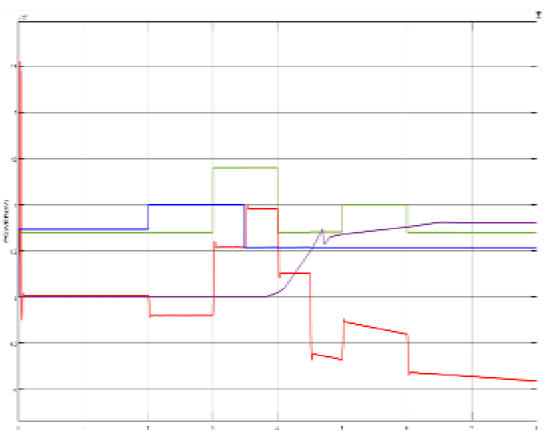

Figure.19 Power generation of the hybrid system under varying AC load

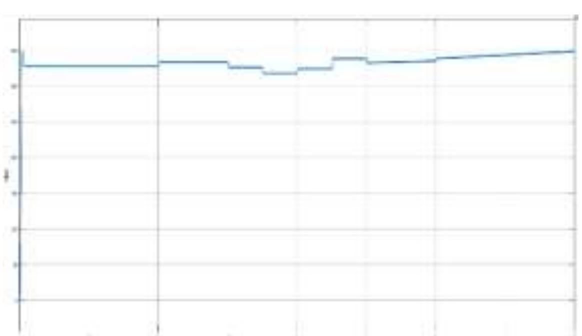

Figure.20 Output voltage battery

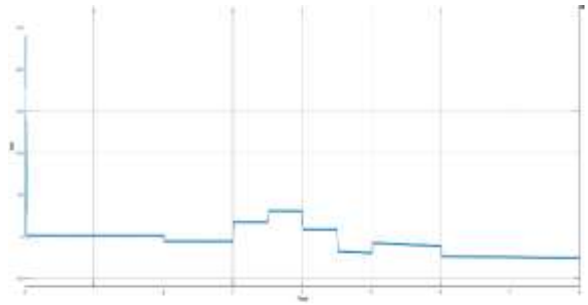

Figure.21 Output current battery

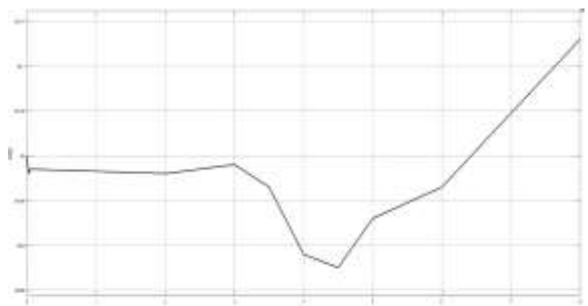

Figure.22 Global state of charge of battery

In Figure 22, we present the global (total) state of charge SOCG of storage devices. From 0 s to 2 s the SOC equals 60 %, and the system operates with full charge.

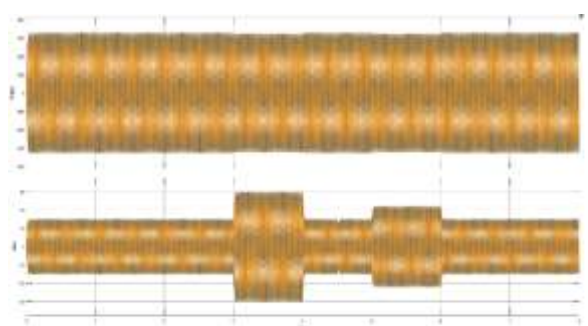

Figure.23 Output voltage and Output current for inverter

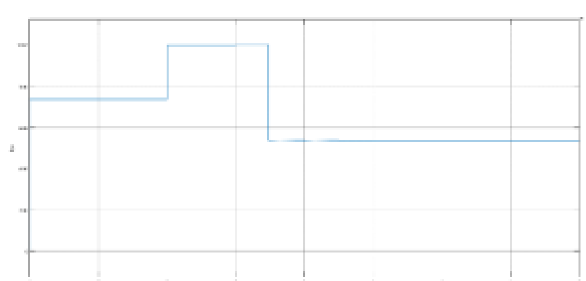

Figure.24 PV Power

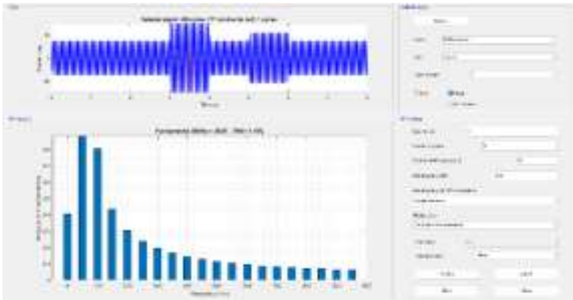

Fig.25 THD% Inverter Output current

COMPARSION TABLE

	Existing System	Extension System
THD% Output current	**3.72%**	**1.10%**

CONCLUSION

In this paper, a novel FOPID controller is proposed for the Energy management of hybrid energy sources contacted to a load through a DC-link voltage. The hybrid energy sources integrated to the DC-microgrid are constituted by a battery bank, wind energy, and photovoltaic (PV) energy source. A three-level inverter is used to convert output from solar and wind systems into AC power output. Circuit Breaker is used to connect and disconnect an additional load in the given time. This hybrid system is controlled to give maximum output power under all operating conditions to meet the load. Either wind or solar system is supported by the battery to meet the load. Also, simultaneous operation of wind and solar system is supported by battery for the same load. These results show the efficiency of the management and the controls used for this hybrid system and can be implemented easily with MATLAB/SIMULINK.

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