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Adaptive Control for Power Management Based on Renewable Energy

***Abstract**. A special form of energy system that can be utilized to provide all the energy needed in the globe is the renewable hybrid system. In order to successfully use renewable energy and decrease the amount of energy drawn from the power grid, a micro-grid management technique based on renewable energy has been developed in this study. The utilization of renewable energy sources, such as solar energy from photovoltaic panels and wind energy (from wind turbines), may run loads more effectively while consuming less fuel. To regulate the electricity, an adaptive control system was also created. The performance of the suggested control method for managing power flow is demonstrated by simulation results acquired using MATLAB/Simulink in a variety of operating modes.*

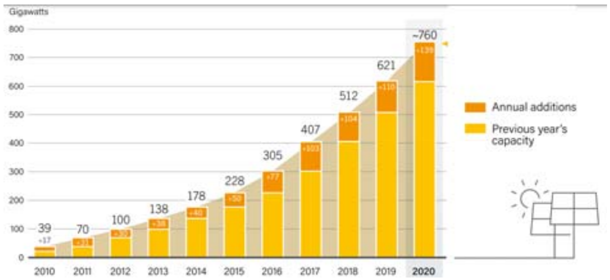
Streszczenie.** Specjalną formą systemu energetycznego, który może być wykorzystany do dostarczenia całej energii potrzebnej na świecie, jest odnawialny system hybrydowy. W celu skutecznego wykorzystania energii odnawialnej i zmniejszenia ilości energii pobieranej z sieci elektroenergetycznej, w niniejszym opracowaniu opracowano technikę zarządzania mikrosieciami opartą na energii odnawialnej. Wykorzystanie odnawialnych źródeł energii, takich jak energia słoneczna z paneli fotowoltaicznych i energia wiatrowa (z turbin wiatrowych), może efektywniej obsługiwać obciążenia przy mniejszym zużyciu paliwa. Aby regulować energię elektryczną, stworzono również adaptacyjny system sterowania. Wydajność proponowanej metody sterowania przepływem mocy została zademonstrowana na podstawie wyników symulacji uzyskanych przy użyciu MATLAB/Simulink w różnych trybach pracy. (Sterowanie adaptacyjne do zarządzania energią w oparciu o energię odnawialną**)

Keywords: power management, hybrid system, distribution generators, renewable energy.
Słowa kluczowe: zarządzanie energią, system hybrydowy, generatory dystrybucyjne, energia odnawialna.

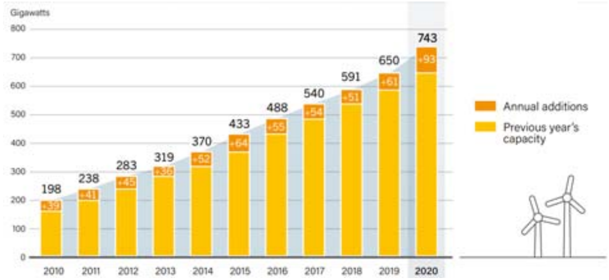
Introduction

The request for power increments quickly when compared to the era. Subsequently, there's a requirement for an elective approach to fulfill the request. As “Energy Moderated is Break even with to Vitality Created". Most customary power-generating plants run on fossil control and deliver 64.5% of control around the world [1]. These control plants have a greater share in carbon outpourings, where generally 40% of carbon is transmitted by the period division, and the transport division [2] produces 24%. Besides, to reach the radically expanding vitality request with lower carbon outflows, analysts have proposed unused strategies of vitality era utilizing renewable vitality sources (RESs). we are centring on diverse ways to control the utilization of vitality this leads to the concept of Stack Side Administration. Request administration alters shopper request through diverse strategies like Smart-grid (SG)operation strategies [3]. SG is characterized as it may be a control supply organization that can cleverly connect the exercises of all clients associated with it like generators, buyers, and prosumers (all those do both time and utilization). SGs work with unmistakable sorts of contraptions such as quick meters (SMs), quick machines, RESs, and batteries. Due to stresses approximately the environment and the economy, there has been an increase in intrigued within the creation and administration of renewable vitality in later a long time [4]. The first move is Hybrid wind was the first renewable energy source to be integrated. as supplementary sources, and solar systems as a remedy for applications in remote areas and shaky grid connections. Further hybrid systems, including a number of them, have been used in study. sources of miniaturized renewable energy including solar thermal, biomass, tidal power and fuel cells [5]. Following the output price to wind turbine and solar panel uses of decreased were drastically decreased, and now they are the only option. for systems that generate hybrid energy [6]. The most objective is to encourage buyers to play down the utilization of control amid top hours, but this cannot be done abruptly. Then again, renewable vitality sources can be coordinated with the framework which decreases the control expended by the framework [7]. The term "Smart Grid" refers to this connection. Since production is now decentralized, the new system improves electricity quality, which is the primary driver of institutions' dependability of the power system, smart grids (SG) connect small power production units, mostly from renewable sources, and employ sophisticated control technology [8]. Right now, renewable vitality share around the world is as it were 11% whereas it is anticipated to extend by 60% in 2070 [9]. The worldwide capacity of wind and sun-oriented photovoltaic (PV) is expanded to 514.8 GW and 399.6 GW individually [10]. Figure 1 appears the global trend for speculation within the PV and wind renewable vitality divisions [11]. In this study, the styling of a smart grid for host structures is given as shown in Figure 2. The submitted smart grids central power sources are wind turbines and photovoltaic for sun and the main grid supply. A management system is constructed to keep track of and oversight the loads into a structure for to achieve the right equilibrium among the energy created and consumed. Adaptive neuro fuzzy system designed to manage the power delivered to the consumer with the priority to the renewable energy (solar and wind energies) over the grid.

An administration practices is created to keep off a delightful putting right between the undertaking around and meander which is required by the building's loads. A supervision renewable fight is explained in Figures in [12] location an Egyptian verdant bailiwick organic upon a surly PV/WT/FC to the electrical utility [13]. The blend sincerely moves forward the profit bizarre composition these interface GESs to its possess dynamic more favourably on touching GES taken a toll thought [14]. Alternate study based on the optimum approximation of a hybrid GES cryptogram in Egypt was presented in effort [15]. In reference [16] investigated the used profits of adding renewable ways with the electrical network on provincial action efficiency. In [17] had beholden a commensurability centre of utility clarification and involve date (DG) alternates to decipher the problem of talent grid outages in rural area. The authors in [18] faked the fusing of GES to the electric utility with energy make consistent and environmental problems consideration. In [19] transferable and shred infested with optimization (PSO) mechanisms were applied to economic studies of off-grid GES. This assembly factual adaptive administer obstruction permission neuro-fuzzy feud supply to superintend the power dog-tired to the pressure by weaken the power grid by compensating power from GES utilized PV/WT energies.



(a)



(b)

Fig. 1 Global trends of renewables (a) solar generation (b) wind generation 2010-2020 [5]

The grid-tied system

The PV and WT frameworks make up the two-source renewable vitality system that's talked about in this issue. The essential neighbourhood framework is associated with these renewable vitality sources. An inverter for PV/WT is portrayed in Figure 2.

a. Main local grid

The grid is depicted as an energy source that has the capacity to produce and absorb electric power. The constraints put on power transformers, transmission lines, and other heavy power equipment of the grid have a limit on how much energy can be absorbed or delivered in a particular time period.

b. PV vitality framework model

The created electric control from the PVES is influenced significantly by the irradiance falling on the PV as well as

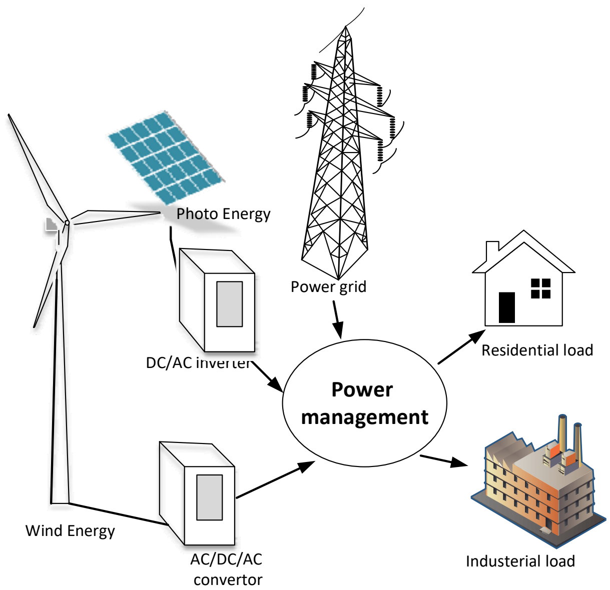


Fig. 2 Hybrid energy system

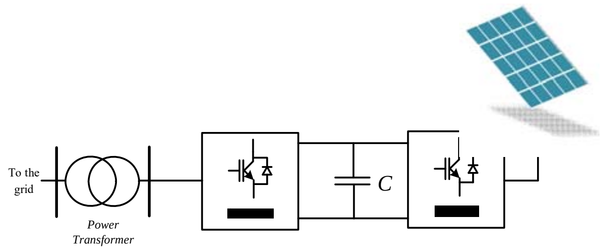
its area. To extend the irradiance and subsequently, the created vitality from the PV framework it is suggested to tilt the PV modules with a perfect tilt point. This perfect tilt point is chosen to break indeed with the scope point of the area [20]. The hourly produced control from the PV cluster can be decided by the taking after condition [21]:

(1)

$$P_{pv} = P_{rated} N_{pv} D_f \left(\frac{G}{G_{ref}}\right) \times \left(1 + K_T \left(\left(T_{amb} + G\left(\frac{NWCT - 20}{0.8}\right)\right) - T_{ref}\right)\right)$$

Where: P_{PV} Produced power of photo voltaic (kW); P_{rated} Output power of module (kW); N_{PV} PV modules number; D_f PV derating factor ; G Titled plane global utility fallen (kW/m^2); G_{ref} Solar radiation at base conditions (1 kW/m^2); K_T Temperature coefficient ; T_{amb} Ambient temperature (◦C); NWCT Normal working cell temperature

The solar model shown in Figure 3.



Fig/ 3 PV energy system model

The height of the anemometer, which should be adjusted to the height of the wind turbine, is used to measure wind speed [22]. Equations illustrate the relationship between the anemometer height and the wind speed to any height are:

(2)

$$P_W = \begin{cases} N_{WT} \times \eta_W \times P_r \times \sum_{t=1}^{T} \left(\frac{V(t)^3 - V_{Ci}^3}{V_r^3 - V_{Ci}^3}\right), & V \leq V_r \\ N_{WT} \times \eta_W \times P_r, & V_r \leq V \leq V_{co} \\ 0, & V_{co} \leq V \text{ or } V \leq V_{ci} \end{cases}$$

Where: P_w Produced power of the wind turbine (kW); N_{WT} Number of the wind turbines; P_r Rated wind turbine power (kW); V_{ci} Cut-in wind speed (m/s); V_{co} Cut-on wind speed (m/s); V_r Rated wind speed (m/s); ηw Wind turbine efficiency

The wind model shown in Figure 4.

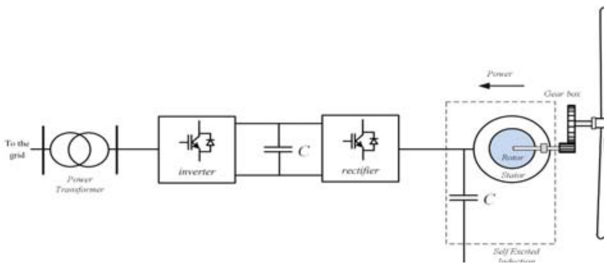


Fig. 4 Wind energy system model

d. Inverter

Both the WT and PV framework create DC vitality. A DC association is joined to the two GREs' DC yield [23]. An inverter is required to put through this DC connection to the electrical lattice at the AC transport. Due to the reality that the proposed on-grid half-breed framework consolidates a battery (as a storage framework), the inverter utilized may be a bi-direction sort to empower charging the batteries from the AC side within the occasion that the REGs' yield control is deficient, as already portrayed in Figure 2. The prerequisite for crest stack for the most part decides the measure of the inverter:

(3) $$P_{inv} = P_{Lmax}/\eta_{inv}$$

Where: P_{inv} Output power (kW); P_{Lmax} Demand power (kW); η_{inv} Inverter efficiency

e. Grid power system model

The grid is shown as an energy source that has the capacity to produce and absorb electric power [23]. There is a limit on how much energy can be absorbed or delivered in a given time period due to the limitations placed on power transformers, transmission lines, and other overwhelming control gear of the network. A Diesel Generator DG is utilized to fulfill a high-power shortage amid the 24-hour day to supply the stack. Depending upon the fuel utilization of DG can be assessed the yield control [24]:

(4) $$P_{DG} = (F_{DG} - (\alpha \times C_{DG}))/\beta$$

Where: P_{DG} diesel generator output (kW); F_{DG} rate of fuel consumption in Ltr/hr; α coefficient of fuel intercept in Ltr/kWh; β fuel slope in Ltr/kWh; C_{DG} capacity of diesel generator in kW

Adaptive control design

Fuzzy logic controllers (FLC) are appropriate for uncertain systems, particularly for systems whose mathematical models are challenging to generate. In a variety of real-world applications, FLC is crucial [25]. There are many other kinds of fuzzy inference systems, however in this study the Takagi-Sugeno TS-fuzzy is used. The Artificial Neural Network (ANN) will be employed with a TS-fuzzy-like-PI controller to modify the membership functions. This kind (TS-fuzzy controller) features a highly nonlinear controller with variable gain, which results in a large range of changes in the controller's gain. Randomly selecting the controller settings may result in a system with an adequate in responsiveness or unitability. By combining ANN with fuzzy logic in a neuro-fuzzy system to change the controller's settings, it is possible to get a better response [26].

By using an artificial neural network (ANN) as a learning method, fuzzy rules are learned. Without the expert knowledge often necessary for the usual form of FCL, such control may be learned, and the rules base can be reduced. Training phases establish the input control parameters and output of membership functions (MF). The goal of the learning algorithm is to modify the input parameters and output MFs to get the optimal output alignment for the proposed controller [27]. The control parameters of a network are often identified using a hybrid learning technique called "Least Squares Estimate-LSE and Gradient Descent-GD" [28]. In the current study, the controller grid power's two inputs were generated by solar and wind energy. Wind turbine power and PV power with one output for power load decision to the control unit of DG the structure as shown in Figure 5. Structure breaks the universe for discourse into three-triangle MFs with a 50% overlap, followed by controller inputs and control p controller generates "three inputs and one output", with a control rule of 9 as a result, requiring the specification of linear functions. One piece of data must be produced in order to tweak the TS rules using neuro-fuzzy. The controller's input data consists of data vectors with PV/WT results that follow Equations 1 and 2, with the controller's output going to the DG control unit. Figure 6 depicts the control designer's output validation surface. The MATLAB-GUI for neuro-fuzzy file contained in the toolbox of MATLAB/fuzzy is employed to carry out the training operation.

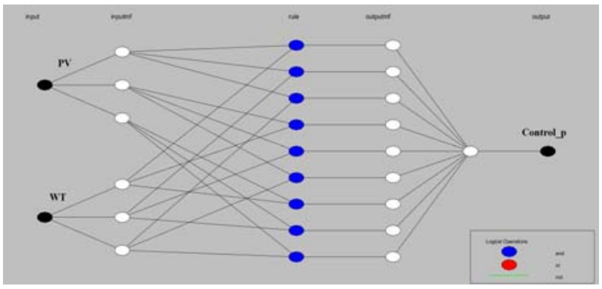


Fig. 5 Neuro-fuzzy control structure

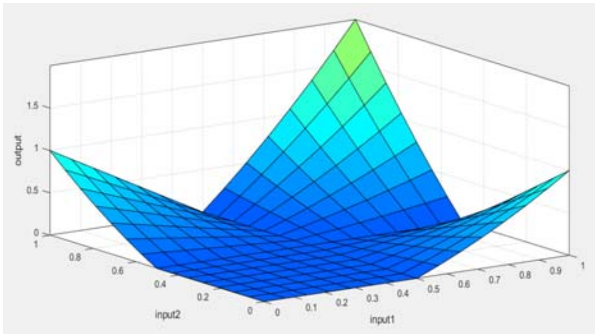


Fig. 6 Wind energy system model

Simulation results

The proposed system model consists of feeder with load branch of 14 MW. Two scenarios are investigated as:

Scenario I

The supplied by three sources the main grid supply with 15 MW, and variable wind energy with maximum power of 4.5 MW as shown in Figure 6 and solar energy with 8 MW in time interval from 6 am to 18 pm as shown in Figure 7. The adaptive neuro-fuzzy controller programmed to give the priority for supply for wind and solar energies to decrease the supply from the grid this will decrease the fuel and then

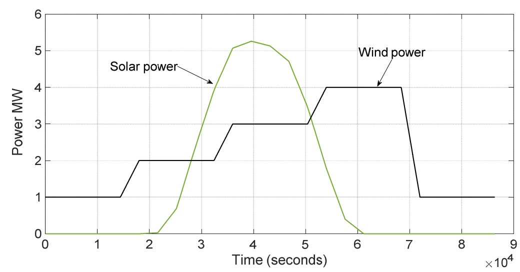


Fig. 7 Solar/wind power per day (scenario I)

operate more economic. The proposed power management of the system algorithm is illustrated in Figure 8. The time calculated based on 24 hours (60*60*24 sec). The real and reactive power demand of the load for 24 hours is shown in Figure 9, also the load voltage shown in Figure 10 respectively.

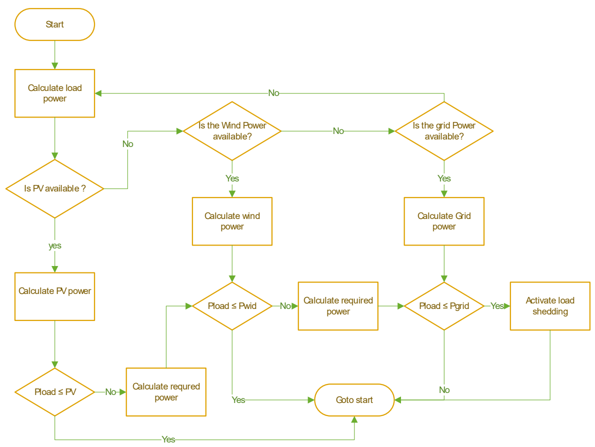


Fig. 8 A proposed power management philosophy

decrease the supply from the grid to obtain more economy operation the increase the supply from wind and solar at their peak's operation 8 MW for solar and 4.5 MW for wind the summation of the two renewable energy is about 12.5 MW and this will compensate the load when increased to 1.5 pu about 21 MW where decrease the supply from the

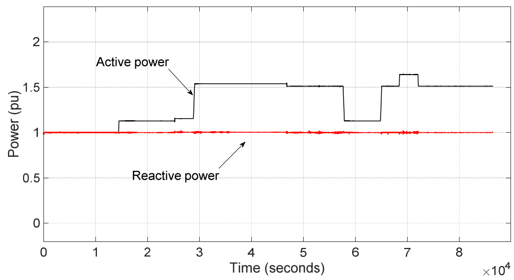


Fig. 9 Load demand power

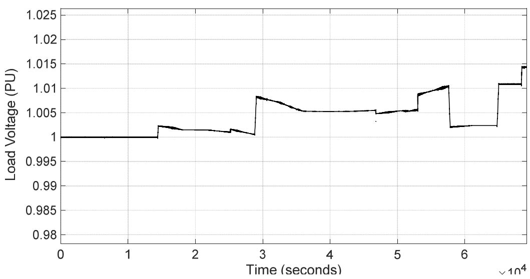


Fig. 10 Load voltage

grid to less than 0.5 pu about 7 MW at time 4.

Managed powers of grid, wind and solar shown in Figure 11.The test starts by feeding the load first by the main grid supply at time 1.45 the wind energy starts to share the load and increase to supply causing to decrease the grid supply and become more economy, at time 2.5 the solar energy starts and share the load with the wind energy and decrease the supply from the grid to obtain more economy operation the increase the supply from wind and solar at their peaks operation 8 MW for solar and 4.5 MW for wind the summation of the two renewable energy is about 12.5 MW and this will compensate the load when increased to 1.5 pu about 21 MW where decrease the supply from the grid to less than 0.5 pu about 7 MW at time 4 . the powers scenario of grid, wind and solar shown in Figure 11.

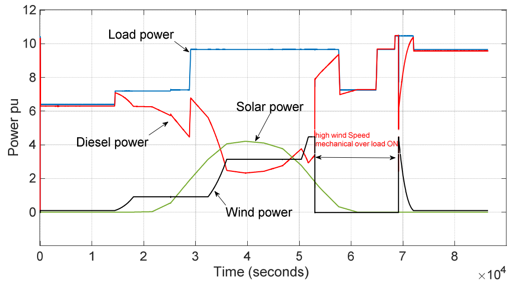
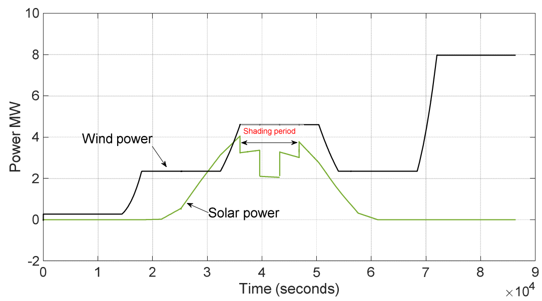


Fig. 11 The managed powers per day (scenario I)

From Figure 11 it can be notice that decreasing the fossil fuel stations by using renewable energy, the compensate the power from renewable energy reach about 50% and this will decrease the total cost of operation.

Scenario II

Wind power and solar power are varied as depicted in Figures 12. Managed power is shown in Figure 13.



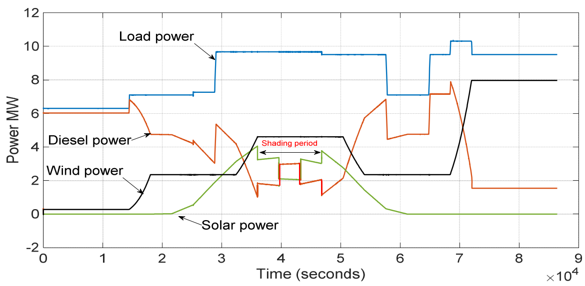


Fig. 13 The managed powers per day (scenario II)

Conclusion

In this work, adaptive control designed for grid-tied hybrid clean energy is presented by MATLAB simulation. A system includes solar cells, a wind turbine, and a diesel generator. Adaptive neuro-fuzzy controller proposed to manage the power feeding to the load. Simulation results guarantee the optimum operation and energy management. The theory used in this work is to reduce the economic expenses of a PV/wind/ hybrid system connected with the grid while also enhancing the system for potential variations in load. Two scenarios are proposed to validate the theory of control system. The results shows an appropriate solution for hybrid renewable energy connected to the grid.

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