Energy Management of Wind/PV and Battery Hybrid System with Consideration of Memory Effect in Battery

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Abstract--**Basic In the districts where solar energy and wind energy are naturally complementary, the application of wind-solar hybrid energy systems can reduce the storage capacity of batteries and the total cost of the system compared with stand alone PV or wind generation system. But efficient and reliable operation of wind-solar hybrid generation system largely depends on control strategies of the controller. In this study, linear short term prediction of wind and solar will be used in regard with energy management of wind/PV hybrid system with battery storage system and its new control strategy. Due to achieving of this goal at first, each subsystem of this hybrid system should be modeled. Then system control strategy with consideration of memory effect will be modeled and finally if it needs the other prediction methods will be comparing to the result of our system. In this system with short term prediction of wind and solar plus applying suitable control methods, the hybrid system will be optimized economically. Due to this purpose all wind turbine and PV arrays and battery will be modeled in MATLAB-simulink then the strategy of control will be applied to optimize the system.**

Index Terms--**Battery Memory Effect, Energy Management, Optimization, Power Electronics, Wind/PV Hybrid System**

I. Introduction

Today renewable systems as a result of renewable energy's improvement and oil's price increase are in center of attention due to power generation in areas which are far from power network [1]. The financial benefit of these resources is a good trigger for governments to invest on them. Researches and developments in renewable energies such as solar and wind and etc. should be paid attention more, till the efficiency of them, precise prediction of their output and the hybrid form of them improved.

All renewable systems have some deficiencies in which the most important one of them is their uncertain output and uncertain prediction of them. Therefore due to their complementary effect of them on each other the hybrid renewable systems with different sources and proper control strategy can be suitable potential of producing power with a good certainty. Also using of energy storage systems to compensate lack of energy is the good method to relinquish the uncertainty of the renewable sources [2].

In this study, linear short term prediction of wind and solar will be used in regard with energy management of wind/PV hybrid system with battery storage system and its new charge control strategy. Due to achieving of this goal at first, each subsystem of this hybrid system should be modeled. Then battery charge control strategy with memory effect consideration will be modeled and finally if it needs the other prediction methods will be comparing to the result of our system.

The recommended system in this study embraces a wind turbine, a PV arrays and a back up battery which are stand alone and far from the power network. Fig. 1 shows the schematic of the recommended system in this study. In this system, Wind and solar energy are the primary resources of producing power, and battery is the back up storage system. This system is a green energy producer because all parts of it are clean energy sources

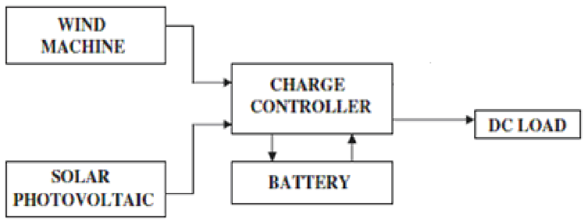

Fig. 1. Schematic of proposed system

A. The Importance of Prediction

Prediction of wind and solar to control the system (wind/PV or the battery) with the seconds interval is useful. Linear prediction is a very powerful method of prediction of time series in changeable conditions .a time varying process is such a process which the variables of the function are varying by time. Linear prediction model shows the samples of time series signals in intervals.

Due to providing load without problem and pause, amount of production of each unit should be determined, therefore to achieving certain load providing our production should be predicted precisely. And to avoid of any uncertainty about load providing, a proper storage battery will be used.

B. Importance of Battery Charge Controller

Importance of battery charge controller Different types of battery such as NiO(OH), $Ni(OH)_2$ with regard of some reasons will react in their anodes and will cause to memory effect [3]. In this situation the work voltage capacity of batteries will decrease noticeably. This event is the result of charging frequently, battery before discharging completely. So because of the importance of storage unit in hybrid systems, a suitable control strategy should be applied for battery [4].

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II. SYSTEM ELEMENTS MODEL

A. Wind Turbine Model

The energy of wind is the amount that calculates by (1).

$$E_k = \frac{1}{2} m v^2 \tag{1}$$

And the delivered power by turbine rotor from wind will be derived from (2).

$$P = \frac{1}{2} k_m \left(v^2 - v_0^2\right) \tag{2}$$

Where:

p: mechanical power delivered by rotor

V: wind speed before turbine

V_o: wind speed after turbine

$$k_m = \rho A \frac{v + v_0}{2} \tag{3}$$

Finally, the mechanical power of turbine will calculate by (3) [5]-[6].

$$P = \frac{1}{2} \rho A v^3 C_p \tag{4}$$

Where:

C_p: is the rotor coefficient

The ratio of blade top speed by the wind speed is λ and will produce by (4). In this equation R is the blade radius and ω is the rotor speed.

$$\lambda = \frac{\omega R}{v} \tag{5}$$

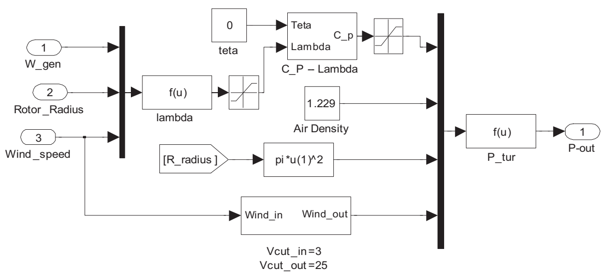

Fig. 2. Wind turbine inside in MATLAB

In Fig. 2, the inside model of wind turbine in MATLAB-simulink is shown and in Fig. 3, the turbine output and TSR–Tip Speed Ratio- trend with regard of wind changes were depicted.

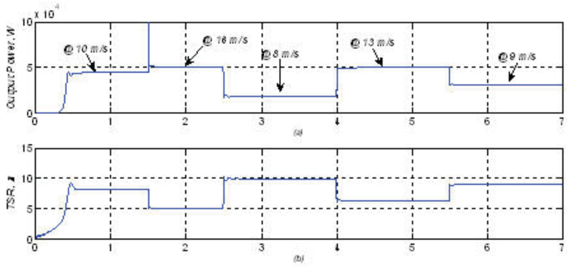

Fig. 3. (a) Wind turbine output (b) TSR

B. PV Model

The model of PV cell is like a current source plus a diode as Fig. 4.

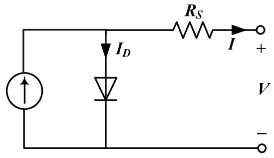

Fig. 4. Electrical model of PV cell

I_{ph} is constant and v is the voltage of cell and I_o is the saturated current.

$$I = I_{ph} - I_D = I_{ph} - I_0 \left(e^{\frac{e(V + IR_s)}{mkT_c}} - 1 \right) \tag{6}$$

In this equation m is the ideal factor and k is Bultsman constant.

$$V_{oc} = \frac{mkT_c}{e} \ln\left(\frac{I_{ph}}{I_0}\right) = V_t \ln\left(\frac{I_{ph}}{I_0}\right) \tag{7}$$

In (7) V_t is the thermal voltage and T_c is the cell temperature [5]-[6].

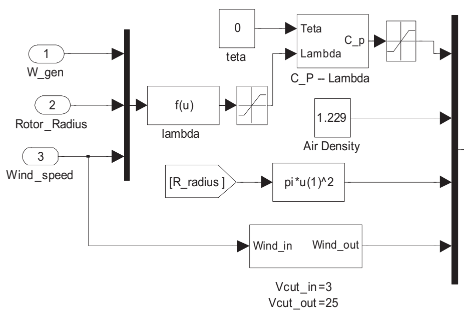

Fig. 5. PV subsystem inside

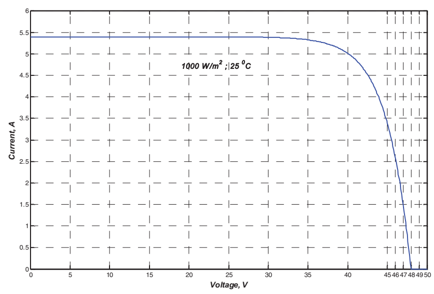

Fig. 6. PV subsystem output

Fig. 5 is the inside model of PV in MATLAB-simulink and Fig. 6 is the model output.

C. Battery Model

Generally battery model is close to a voltage source (E) which is serried with a resistance R_o (Fig. 7).

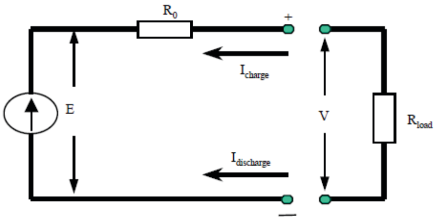

Fig. 7. Battery electrical model

So the terminal voltage of battery is:

$$V = E - IR_0 \tag{8}$$

This model of battery embraced of 2 tanks as it was shown. Tank 1 with width of c and available capacity of q_1 (charge). Tank2 with width of 1-c and limited chemical capacity of q_2 (charge) (Fig. 8).

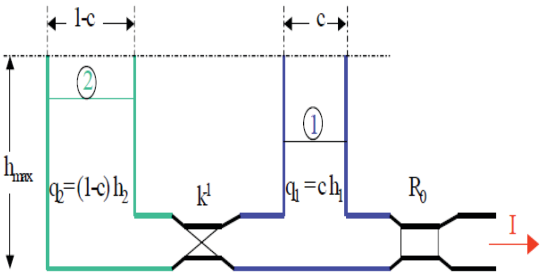

Fig. 8. Schematic diagram of battery

The capacity model of battery will be shown with three parameters k, c, q_{max}. R_0 and the maximum capacity of two tanks are:

$$\frac{dq_1}{dt} = -I - k(1-c)q_1 + kcq_2 \qquad V = E - IR_0$$
$$\frac{dq_2}{dt} = k(1-c)q_1 - kcq_2 \tag{9}$$

D. Two Quadrant Chopper

In this part the interconnection of the hybrid system will be analyzed .therefore the mail part is two quadrant chopper as it was depicted in Fig. 9.

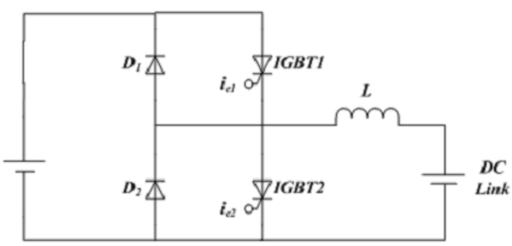

Fig. 9. Two quadrant chopper to charge and discharge of battery

This chopper is used to store the extra power of turbine and PV in battery and to discharge battery banks in the situation of lacking energy in producing of load power. The control strategy of this chopper is depicted in Fig. 10.

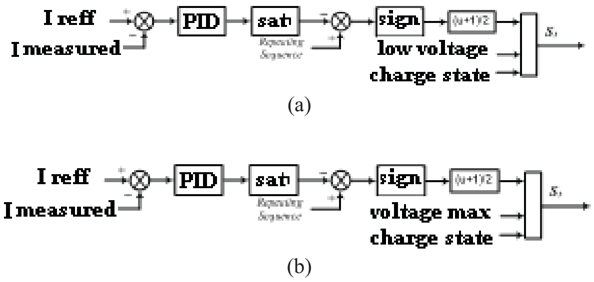

Fig. 10. (a) S_1 for discharge of battery (b) S_2 for charge of battery

And finally due to avoiding of memory effect in batteries the strategy of fast charge and discharge will be applied and to achieving it the value of inductor of chopper will be larger as twice or more. Fig. 11 depicted his solution.

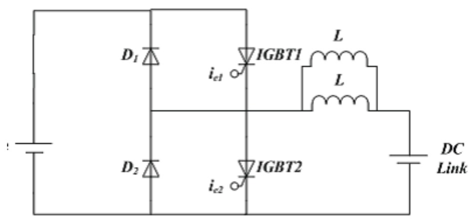

Fig. 11. Schematic of two quadrant chopper to charge and discharge of battery

III. Optimization Results

By using PSO algorithm to optimize the hybrid system economically, the results of battery SOC and system power and load are depicted as follows.

Due to input wind data, hourly wind data for a year was measured and to achieve a more reliable data every week wind data was averaged as a day, therefore it contains that can be seen in Fig. 12. Due to solar irradiation for a year, it was done like wind data which was depicted in Fig. 13.

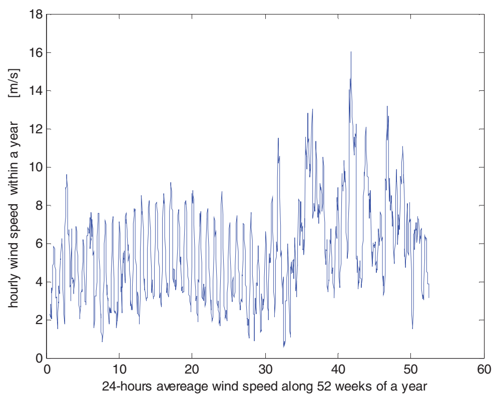

Fig. 12. Wind 24 hours average data among a year in an area of north eastern part of Iran (52 weeks)

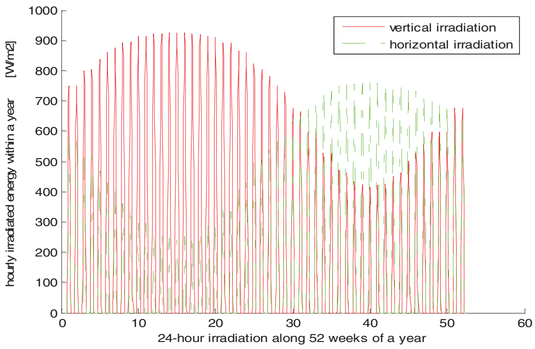

Fig. 13. Solar 24 hours average data among a year in an area of north eastern part of Iran (52 weeks)

In Fig. 14 the abstracted energy of PVs among a year by the applied data of special area which mentioned before was depicted.

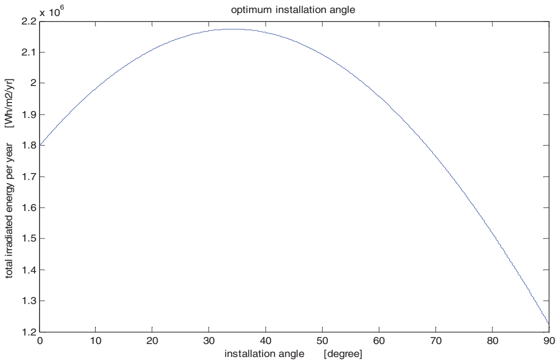

Fig. 14. Solar abstracted energy among a year

As it was depicted in Fig. 15, the battery SOC among a year by our proposed method is not less that 20% be cause of reliability.

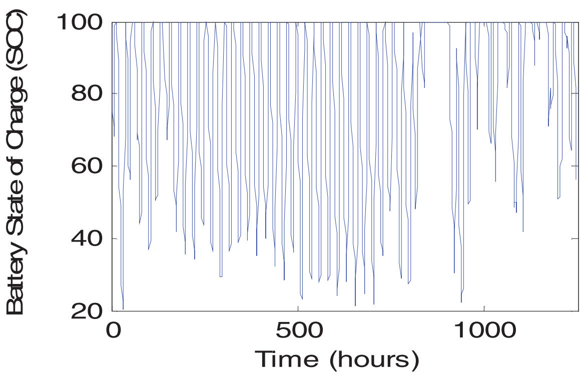

Fig. 15. Battery SOC among a year by this optimized system

Fig. 16 shows the wind turbine and PV array's energy among a year which produces our generation.

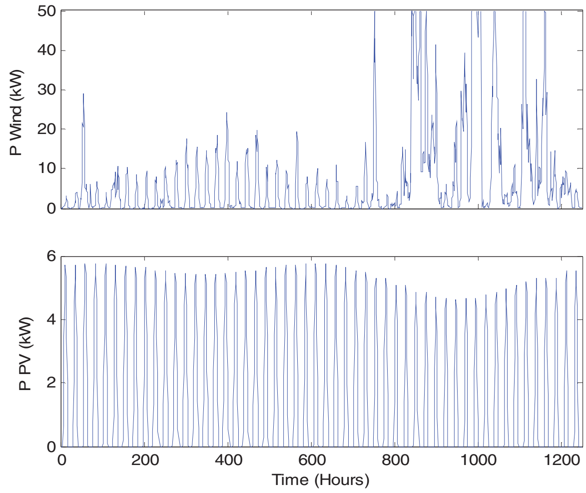

Fig. 16. Wind turbine and PV power among a year

IV. CONCLUSIONS

In this paper we present a new control method for hybrid system of wind-PV and battery with consideration of battery memory effect. by linear prediction of wind and solar in this system and also by fuzzy control method of battery due to charge and discharge ,we can say that this system is reliable and in comparison with other control strategy be cause of considering the memory effect of battery and cost optimization ,it is more practical and reliable.

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