Voltage Profile Correction with Renewable Energy Source in Smart Network

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Abstract

Maintaining the security and network stability, climate changes and environmental issues led to the migration of scientists to renewable energy sources and new technologies. The use of photovoltaic systems, wind turbines and hybrid vehicles are very popular. In this paper, photovoltaic systems, wind turbines and hybrid vehicles are modeled. Then, a control circuit for hybrid vehicle for optimum use in the power network is provided. Finally, on a model network park locating of vehicles considering the hybrid vehicles, wind turbine and photovoltaic systems, is studied and compared in various scenarios. The analysis is based on the simulation results obtained from the MATLAB/Simulink and Digsilent software.

1. Introduction

Due to the growth and complexity that exists in exploiting the power network, the network security has become a major challenge [1]. Smart Grids given the tools (such as advanced measurement tools real time analysis of network, Energy saver devices, etc.) as well as extensive support and participation of governments, merchants, consumers, distribution companies and other stakeholders and increasing knowledge in order to enhance these networks by combining advanced communication technologies are more reliable than existing networks [2]. With the development and use of clean fuels for energy consumption as well as on the international community tendency to make greater use of renewable energy such as solar and wind energy, distributed energy sources are significantly increased. Given the variety and unpredictability of renewable energy sources, especially wind energy, high capacity energy saving systems are required for dispatching these resources.

Today, the increasing threat of climate change and growing concerns about energy security resulting from fossil fuels have prompted scientists to offer new and advanced technologies, to reduce greenhouse gas emissions and dependence on carbon based fuel. In this regard, the use of hybrid and electric vehicles and battery-powered electric vehicles with regard to their effect on the reduction of environmental pollution, the low cost and reduction in the use of petroleum products is of great importance [3-4]. Considering the new battery-powered electric vehicles and hybrid electric vehicles from the standpoint of smart converter a larger battery than old ones the use of these devices in different operating modes is provided.

Many researchers have done researches in this field of various benefits and issues related to implementation of different modes of operation of electric vehicles. Hadley et al studied the effects of hybrid electric vehicles and battery electric vehicles on electricity demand, pricing, manufacturing, infrastructure and the rate of their increase in 2020 and 2030 in 13 areas identified by the North America Electric Reliability Corporation (NERC). According to the technical report of NYISO smart electric vehicle penetration rate will reach 25% by 2030 [5]. Shimzo et al argued the power system frequency control using electric vehicles [6]. Tai et al examined the effects of hybrid electric vehicles on electrical components power systems [7].

In this paper, we first the structure of the power system including fuel cell hybrid vehicles, wind turbine and solar cell will be introduced. Then, control systems for electric vehicles will be proposed. Then, taking into account the costs of a hybrid vehicle, simulation of their performance will be examined. Also, considering a hybrid car, hybrid vehicle, wind turbines and photovoltaic systems park locating of a hybrid vehicle in a typical power grid is done. Finally, voltage profile, voltage profiles sensitivity analysis and its losses as smart grid is evaluated.

2. The Studied System Structure

2.1. Structure of Fuel Cell Electric Hybrid Vehicle

The structure of the fuel cell hybrid vehicle is shown in Fig. 1. As can be seen, on the one hand there is a DC bus and load connected to it. Loads can be considered as a combination of AC and DC loads. Battery, ultra capacitors and fuel cells are connected to DC bus by a DC/DC power electronics converter. For convertors connected to the battery and ultra capacitor bi-directional structures are used for bidirectional transmission of load, and for the converter connected to the fuel cell considering the one-way flow of power a conventional boost converter is used. Mathematical modeling is as follows. Load at the wheel is obtained from below equation [8-9]:

$$P = [R_L + (M + M_r)a]V \quad (1)$$

In the above equation, P , V , a and R_L are respectively the power, movement speed, acceleration, resistance of tires and M and M_r are inertia of wheels.

Engine torque is calculated as follows [8-9]:

$$T_e = \frac{P_e}{\omega_e} \quad (2)$$

In the above equation T_e, P_e and ω_e are torque, power and angular speed of the engine.

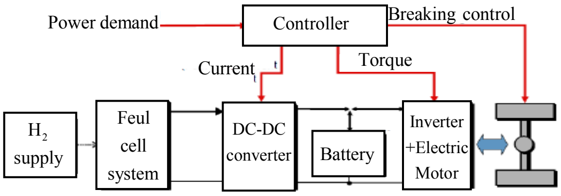

Fig. 1. Structure of fuel cell hybrid vehicles

2.2. Wind Turbine Structure

Energy generated from wind turbines is one of the simplest form of renewable energy. The amount of electric power generated from wind turbines depends on wind regional characteristics of wind such as speed, density and strength, dynamic structure and dynamic behavior of gearbox, type of and wind turbine. Power generated based on wind speed for a particular wind turbine is calculated from the following equation [10-11]:

$$P_{WTG} = \begin{cases} 0 & v < v_{cri} \\ P(A + Bv + Cv^2) & v_{cri} \le v < v_r \\ P & v_r \le v < v_{co} \\ 0 & v > v_{co} \end{cases} \quad (3)$$

In the above equation, v_{cri} , v_r and v_{co} are respectively, nominal, and maximum and speeds size of a wind turbine. Meanwhile, A , B and C are constants of wind turbines.

2.3. Structure of Photovoltaic System

Solar energy is the most unique renewable energy source in the world and is the original source of all energy on Earth. Photovoltaic energy is the conversion of sunlight into electricity through a photovoltaic cell, which is normally done by solar cells. Solar cell is a non-mechanical device usually made from silicon alloys. According to Fig. 2, the equivalent circuit of a photovoltaic cell comprises a source dependent on light on the opposite direction of PN diode. For a solar cell we will have the following equation [12-13]:

$$I = I_{pv} - I_o\left[\exp\left(\frac{V + R_s I}{aV_t}\right) - 1\right] - \frac{V + R_s I}{R_p} \quad (4)$$

Where, I_{pv} and I_o are the current and saturation current of the photovoltaic modules, respectively. Also, R_p and R_s are the equivalent parallel and series resistance.

2.4. Control System Design

DC bus voltage control is open loop. For various modes of operation of an HEV, (the modes of start-up, acceleration, fixed and brake speed reference of each resource, depending on the mode of operation equals to an appropriate fixed amount given and these modes are simulated one by one at 5 seconds. Current control is carried out by pulse width modulation 1. Reference value of each resource currents are compared with the measured values and the difference between them are given to a PI controller. The output of each controller calculates 2 corresponding source duty cycles. This amount is then compared with a triangular wave and the output of the comparator is the command signal that is applied to corresponding converter switches. For two-way convertors, typical double-switch structure is used that acts as a boost converter and on the other hand operates as buck converter. Commands to two switches are complementary to each other. Due to the differences in transmitted power to the DC bus in any of investigated modes, the bus voltage to remain constant different values are used for load resistance so that in each mode, the transferred power to the DC bus in same with the power dissipated in load resistance. For brake mode, given that the kinetic energy is directed to storage batteries and ultra capacitors the load is modeled with a constant current source that can inject specified power to DC bus.

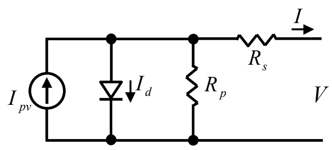

Fig. 2. Equivalent circuit of a solar cell

3. Simulation Results

3.1. Hybrid Vehicle

Inputs related to the consumption of each part of hybrid vehicle System is shown in Fig. 3. Also, for a given consumptions and battery ($50A/hour$ rated capacity), the initial charge of 80% and an initial temperature of 25 degrees, waveforms of Voltage, current, power, SOC and battery temperature are presented in Fig. 4. Waveforms of current, voltage and alternator duty cycle are shown in Fig. 5. In this section for energy control, four modes are simulated: Start or start-up, acceleration, no acceleration mode (moving at a constant speed) or long distance mode and braking. In the simulation, equivalent increases or decreases in engine speed, load resistance are applied, and at conversion of different modes to each other, the load has changed, the reference sources has changed too and the only parameter that was constant is DC link voltage. DC Link voltage is $451V$, DC link capacitor is also $111mF$ and input power is $911W$. At zero to 5 seconds, vehicle at is modeled at startup mode, at 5 to 11 seconds in acceleration mode, at 11 to 15 seconds in move at a constant speed and braking mode is modeled at 15 to 21 seconds. Respectively at these moments, first and fourth switches go on and every time except braking mode that has no resistance and power is produced by the DC motor, resistances with different values are entered in the circuit. In fact, when each of the first and fourth switches do on, the vehicle is modeled in various operating modes. Load resistance for the startup is 315.42Ω , and for acceleration mode and long distance mode it is respectively 211.82Ω and 438.31Ω .

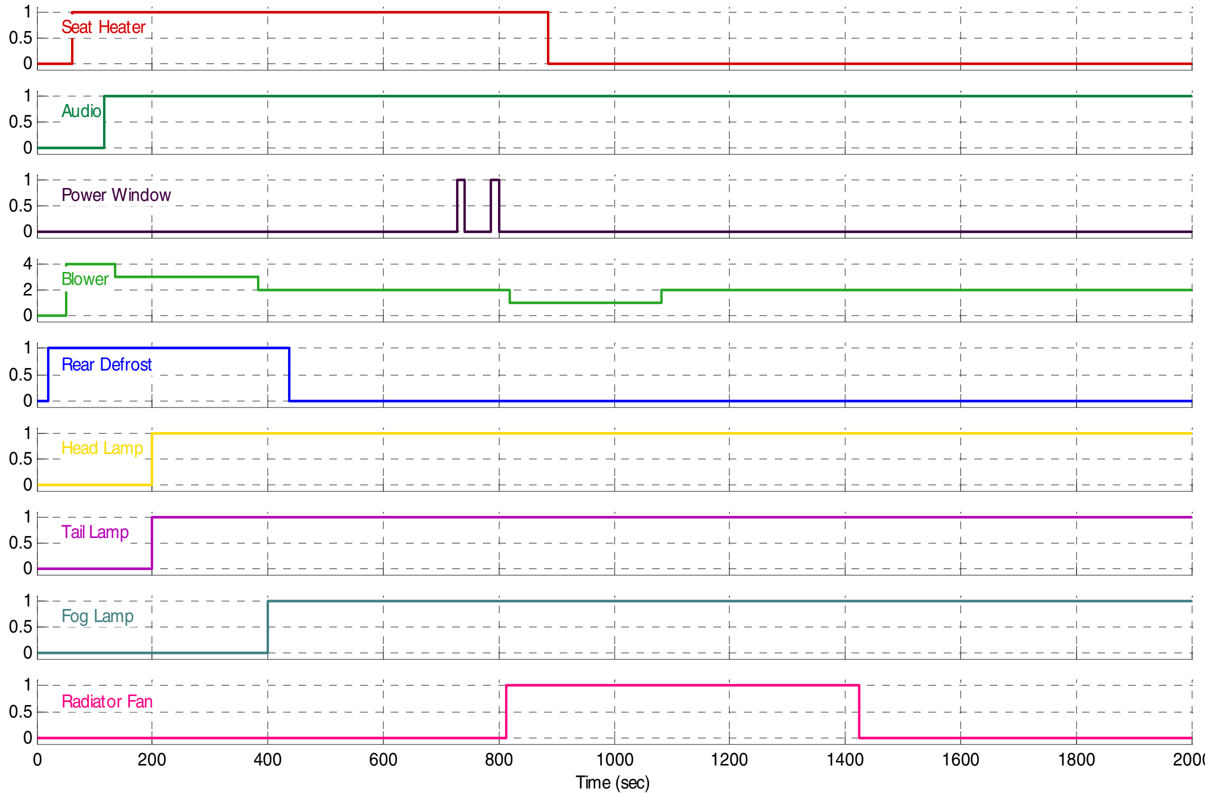

Fig. 3. The consumption of hybrid vehicle

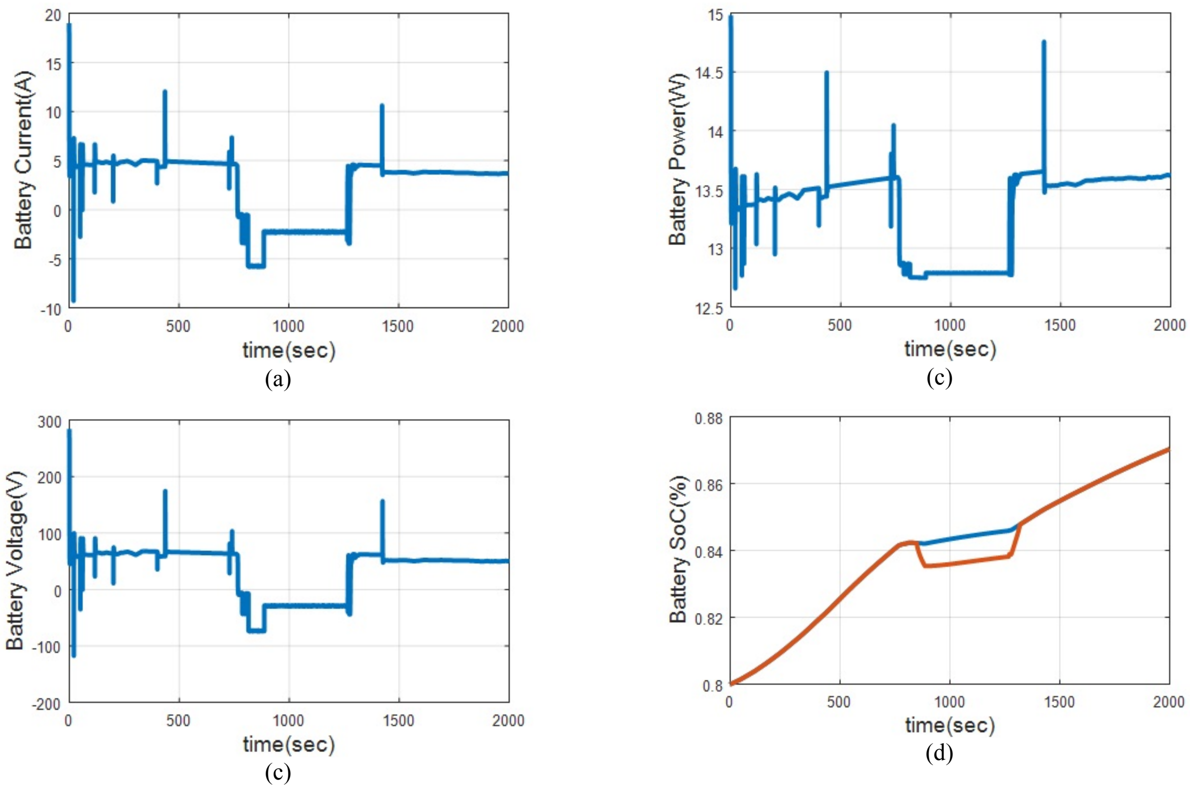

Fig. 4. Waveforms of Battery, (a) current and (b) voltage, (c) power, (d) SOC and (e) temperature

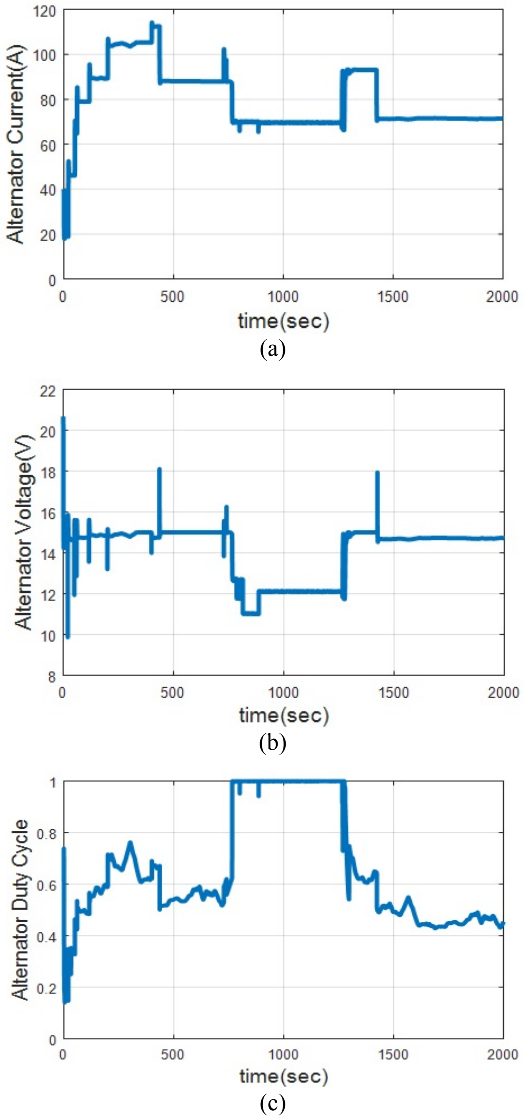

Fig. 5. Waveforms of alternator, (a) current and (b) voltage and (c) duty cycle

3.2. Locating Charging Stations of Hybrid Vehicle in the Network

In this part, the impact of optimal locating of parking for electric vehicles that their batteries are used as a supplier of energy during peak load is examined. IEEE 37-bus network can be considered as a network. It is assumed that the network has wind and photovoltaic renewable energies and hybrid vehicle. The aim is to locate wind and solar renewable energy and smart parking so that can provide network load at the most optimal voltage profile.

Location and amount of energy available in the batteries of hybrid vehicles are variable parameters in optimization. Optimization problem by voltage control in production units continues until they can be in the stable range and there is no instability (except on the slack bus). Since feeder 1, before the fault is supplied through an infinite bus after the fault it is supplied via the vehicle battery and renewable sources. Optimization problem solving is done using Digsilent software. For simulation, the following assumptions are considered:

- Buses 7, 14, 17, 21 and 32 are intended as candidate buses for the location of wind and solar turbines and Smart Parking and to limit the number of states it is assumed that if the wind farm is at bus 17, solar and parking cannot be located in it. Therefore, in total we have $5\times4\times3=60$ number of modes.
- Parking lots have the potential to electric vehicle charging and discharging.
- Bus 1 is where the fault is occurred, after which the error occurred, there is no generators to produce power other than electric vehicles and renewable resources.
- The number of electric vehicles is in such a way that the stored energy is about 0.9 MW.
- Parking lots have capacitor banks that can provide reactive power of feeder at standstill.
- Voltage level is $4.8kV$.

3.2.1. The Simulation Results and Locating to Improve the Voltage Profile

In this part, chart of network voltage profile after performing the three-phase unbalanced load flow in Digsilent for five different scenarios is provided as follows:

1. Wind turbine is located on bus 7. Therefore, we have 12 modes for photovoltaic systems and smart parking. It means that photovoltaic system is located on one of 14, 17, 21 and 32 buses and parking can be located on three remaining buses
2. The wind turbine is located on bus 14 and …
3. The wind turbine is located on bus 17 and …
4. The wind turbine is located on bus 21 and …
5. The wind turbine is located on bus 32 and …

Comparison of scenarios

In this section, the best profiles for each scenario are compared with each other to determine the most efficient locations possible for renewable and smart parking. Fig. 6 shows the comparisons. It can be seen that in all scenarios presented, bus voltage is between 0.9 to 1 pu and the best mode is for the following two cases:

- Wind turbine is on bus 21, solar is on bus 17 and smart parking is on bus 7
- Wind turbine is on bus 17, solar is on bus 32 and smart parking is on bus 21

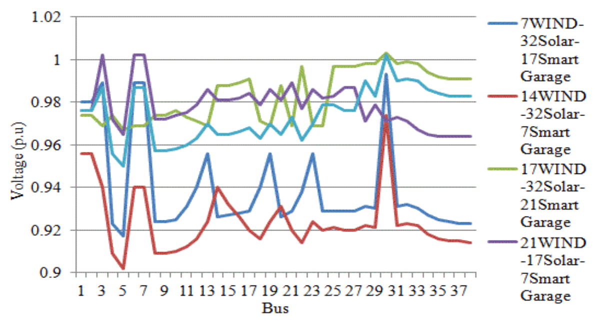

Fig. 6. Comparison of voltage profiles for the scenario

3.2.2. Sensitivity Analysis

(a) Determining the optimal location in terms of voltage profiles: for sensitivity analysis in this section it is assumed that the wind turbine is on bus 17, the solar is on bus 32 and parking

lot is located on bus 21. In addition to power outage from the main power grid at bus 1, the filed between bus 17 with the network downstream is disconnected. In the following the voltage profile is provided for this case. It should be noted that the duration of the intervals is so that available resources can provide network load. Fig. 7 shows the voltage buses has fallen, yet still is not out of range.

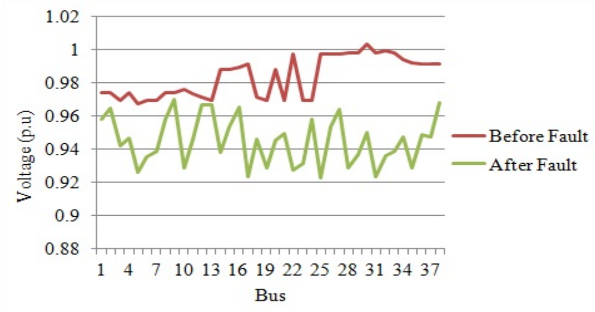

Fig. 7. The voltage profiles before and after the cut of line of bus 17 and 21

(b) Determining the optimal location in terms increasing storage of each hybrid vehicles*:* It is assumed that the available capacity from renewable sources and the amount of storage of each hybrid vehicles have increased by 10%. Fig. 8 shows the voltage profile in this case. It can be seen that this would improve the voltage profile compared to the reference. The amount of network losses dropped from $120kW$ to about $95kW$.

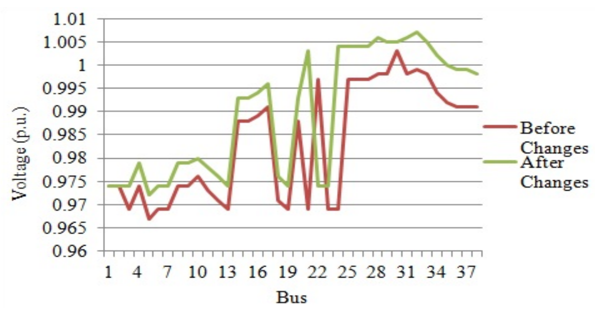

Fig. 8. The voltage profiles before and after the increase in capacity of renewable and hybrid vehicles

4. Conclusion

In this paper, we introduced a fuel cell hybrid vehicle and it was simulated. To use vehicle batteries to provide energy at times of peak energy consumption, parking locating was studied with hybrid vehicles, wind turbines and photovoltaic systems in five different scenarios for IEEE 37-bus system. In the following, profiles, voltage sensitivity and losses were conducted for modeled power grid to determine the most optimal mode. Summary of results are as follows:

- Best mode for the first scenario is when the wind turbine, photovoltaic systems and smart parking are located respectively on buses7, 32 and 17.

- Best mode for the second scenario is when the wind turbine, photovoltaic systems and smart parking are located respectively on buses 14, 32 and 7.

- Best mode for the third scenario is when the wind turbine, photovoltaic systems and smart parking are located respectively on buses 17, 32 and 21.

- Best mode for the fourth scenario is when the wind turbine, photovoltaic systems and smart parking are located respectively on buses 21, 17 and 7.

- Best mode for the fifth scenario is when the wind turbine, photovoltaic systems and smart parking are located respectively on buses 32, 17 and 7.

The scenario when the wind turbine, photovoltaic systems and smart parking are located respectively on buses 21, 17 and 7 and the scenario when the wind turbine, photovoltaic systems and smart parking are located respectively on buses 17, 32 and 21 were selected as the best modes.

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