V2G Simulation for Frequency Regulation in Micro Grid with Solar, Wind and Diesel Power Generation Environment

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Abstract - *This paper presents the vehicle-to-grid (V2G) system connected to the micro grid, which is consist of solar, wind and diesel power generation along with residential and industrial load. In this research V2G effect on the frequency is observe and V2G act as a frequency regulator in micro grid. Total of 100 cars are considered in V2G system which have five different types of car profiles. Ratio between the car and houses is 1:10. Complete Phasor model is modeled and simulated in MATLAB/Simulink. Effectiveness of the V2G is verified by different input conditions. Simulation results shows that for wide range of inputs V2G effectively regulated the grid frequency.*

Key Words: **Vehicle to grid (V2G), Electric Vehicle (EV), Smart Grid, Solar Energy, Wind Energy, Diesel Generator (DG), Micro Grid.**

1. INTRODUCTION

Nowadays, Electric Vehicle (EV) for domestic transportation becoming more promising worldwide. EV have major advantages of pollution free, energy saving and noise pollution free transportation. Ownership of the EVs are increasing, by the end of 2030 it will be 10% worldwide. Manufacturing and Sales will increase to 20M by the end of 2030 [1]. Considering the increasing number of EV, it is important to build a greater number of charging station at appropriate locations to meet required demand. These days, researchers and industries are more focused on EV and their connection to the grid. EVs have capability of energy storage that can be further utilized in some other applications like stability and reliability improvement such as voltage, frequency regulation etc [2][3][4][5].

In addition to being a controllable load, EVs can also act as a distributed power storage device for grid input power (vehicle-to-grid, V2G). Therefore, EVs will theoretically provide ancillary resources for the grid, such as frequency control [6][7][8][9]. EVs have facility to charge at home, public places or parking lots with quick charging facility. EV are not yet another load in the current power system grid [10]. High electricity demand by the number of increasing EV will become crucial load on the electric grid. Renewable energy sources (RES) play vital role to fulfil future demand without harming environment and producing clean energy to meet demanded load. Most of the studies explained that among all RES, solar energy and wind energy is most promising source of clean energy. Most of the available literature uses solar power generation either in stand-alone mode or grid connected mode along with other energy sources. The diesel generator (DG) set demand will continue to increase as to deal with unexpected power outages. Environmental factors like weather, wind speed, solar irradiation affect the power generation. Due to that EV will not charge continuously from solar energy or wind energy. As result of this it is important to add some sort of energy source to the system that can fulfil the load demanded by EV. So proposed system consists of solar energy, wind energy along with additional DG set.

In this paper, EV contribution in microgrid supply and frequency regulation is analyse. This paper is divided into several section and organized as follows: section 1 defines the importance of V2G system in micro grid. In section 2, proposed system is described. Section 3 defines the control of the system, in section 4, simulation scenario and simulation results are discussed. Finally, in section 5 conclusion is described.

2. STRUCTURE OF PROPOSED SYSTEM

The proposed microgrid consists of four parts: two parts RES as PV farm combined with wind farm; a diesel generator act as a reserve to support the load power demand; at the end of the system V2G system and the load are connected.

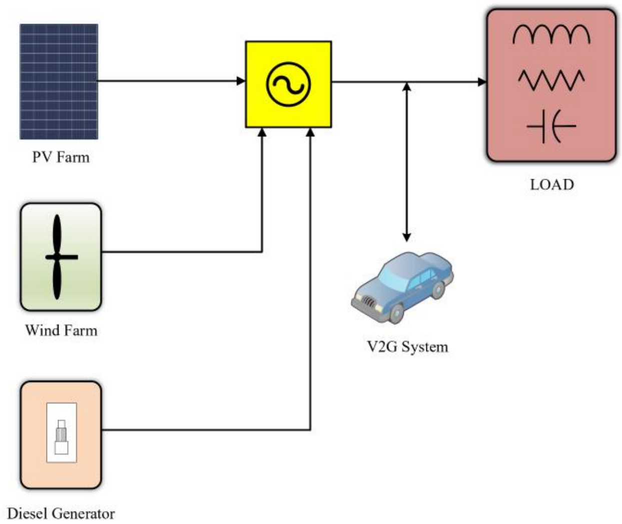

Fig -1: V2G connected microgrid configuration

The discussed configuration of microgrid is shown in figure 1. The proposed system consists of 8 MW PV farm, 4.5 MW wind farm, 15 MW diesel generator, 4 MW V2G and 10 MW. In this system thousand households as community is considered and hundred EV that means there is 1:10 ratio between EV and households. This may be the possible scenario in near future.

2.1 PV Farm

A PV farm produces energy proportional to three factors: the size of the area covered by the PV farm, the efficiency of the solar panels and the irradiance data.

2.2 Wind Farm

A wind farm produces electrical power following a linear relationship with the wind. When the wind reaches a nominal value, the wind farm produces the nominal power. The wind farm trips from the grid when the wind speed exceeds the maximum wind value, until the wind gets back to its nominal value.

2.3 Diesel generator

The diesel generator balances the power consumed and the power produced. Whenever there is power shortage from the PV and wind farm, diesel generator fulfils the load demand. It acts a power balancer in the proposed system.

2.4 Vehicle to grid

The V2G has two functions: Controls the charge of the batteries connected to it and uses the available power to regulate the grid when an event occurs during the day. The block implements five different EV-user profiles:

Profile-1: People going to work with a possibility to charge their EV at work

Profile-2: People going to work with a possibility to charge their EV at work but with a longer ride

Profile-3: People going to work with no possibility to charge their EV at work

Profile-4: People staying at home

Profile-5: People working on a night shift

2.5 Load

The load is composed of residential load and an asynchronous machine that is used to represents the impact of an industrial inductive load (like a ventilation system) on the microgrid. The residential load follows a consumption profile with a given power factor. The asynchronous machine is controlled by a square relation between the rotor speed and the mechanical torque.

3. CONTROL OF V2G FOR FREQUECY REGULATION

The EVs participation in AGC from a broader perspective is used in developing a mathematical model of EVs. Secondary frequency regulation is primarily accomplished by control action with area control error as input to controller. EVs for vehicle-to-grid process need to be modelled by keeping in view of change in frequency and AGC control signal. Communication channels between AGC and EVs are simplified and designed as an aggregated EVs model for secondary frequency control. The State of Charge (SOC) of electric vehicles is noted at every instant to have the correct accumulated capacity of all available EVs for frequency regulation. Therefore, EVs are basically used as reserve capacity to cater at the time of sudden demand in power system, and this would be the case in peak hours during a load cycle. The inputs are controller output and change in frequency to the aggregated model of EVs for V2G as shown in figure 2 The prime purpose of having EVs grouped together is that they represent a virtual large energy storage plant with a enough capacity to support AGC at the time of peak demand or sudden demand during the course of power supply at any other time.

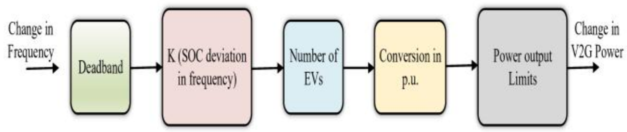

Fig -2: Vehicle to grid (V2G) for AGC

4. SIMULATION RESULTS AND DISCUSSION

In this study, model is simulated for 24-hour scenario. The solar intensity follows a normal distribution where the highest intensity is reached at midday. The wind varies greatly during the day and has multiple peaks and lows. The residential load follows a typical pattern similar to a normal household consumption. The consumption is low during the day and increases to a peak during the evening, and slowly decreases during the night. In this case study two partial shedding effects are considered whose details are given in Table 1. Industrial load is turned on at 3 Hr. Cars profile chosen for this case is shown in Table 2. Further details of the simulations results are discussed below.

Table -1: Shedding effect

Partial Shedding No	Event Occur at	Duration	Factor
1	12 Hr	10 min	0.7
2	14 Hr	15 min	0.5

Table -2: EV profiles

Profile Name	Number of Cars
Profile-1	20
Profile-2	30

Profile-3	20
Profile-4	10
Profile-5	20

Figure 3 shows the simulation results of irradiance, power, voltage and current. As seen from the figure power generation is peak at midday. Generation of PV farms varies according to the solar irradiance. Peak power generated by the PV farm is 4 MW. At peak period current is about 145 Amp. Partial shedding effect can be clearly seen at 10 Hr and 12 Hr with duration of 10min and 15min respectively.

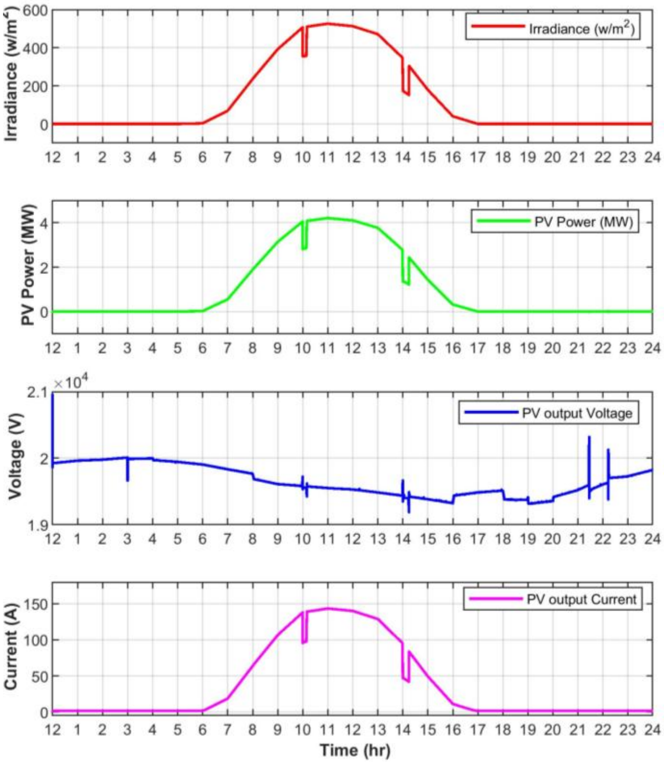

Fig -3: PV Farm Solar Irradiance, Power, Voltage and Current Simulation Results

Figure 4 shows the simulation results of wind speed, power, current and voltage. In this maximum wind speed is considered as 14 m/s. Wind has intermittent nature which can be seen in the figure. Peak power generated by the wind farm is 4.5 MW. Wind farm has protection against the high wind speed so get tripped when wind speed crosses the maximum wind speed limit. This interrupt event occurs at 21:45Hr as seen in the figure 4.

Figure 5 shows the simulation results of diesel generator power, current and voltage. Diesel generator regulate the power demand. Peak power generated by the diesel generator is 14 MW.

In this study, residential load of total 10 MW and industrial load of 0.16 MVA is considered. Residential load power, current and voltage results are shown in figure 6. Industrial load is turned on at 3Hr. Industrial load power, current and voltage results are shown in figure 7. Figure 8 shows the industrial load that is asynchronous machine simulation result like power, rotor speed, Electromechanical torque and mechanical torque.

100 cars are connected of each 40 kW. Total V2G load is 4 MW. 100 cars are divided into total five types of profile as presented in table 2. Charging voltage and current results are shown in figure 9. Figure 10 displays the number of cars in charging mode and number of cars in regulation mode. Figure 4.11 shows the all profiles cars SOC results.

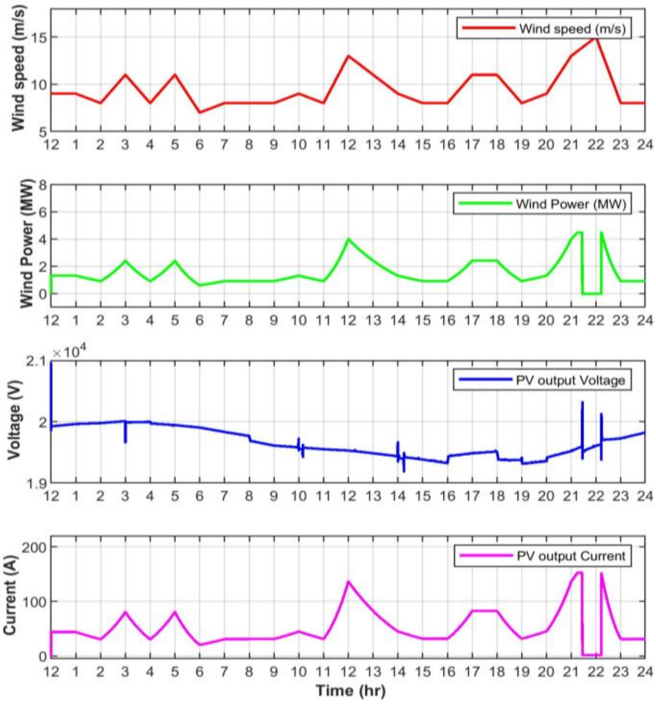

Fig -4: Wind Farm Wind Speed, Power, Voltage and Current Simulation Results

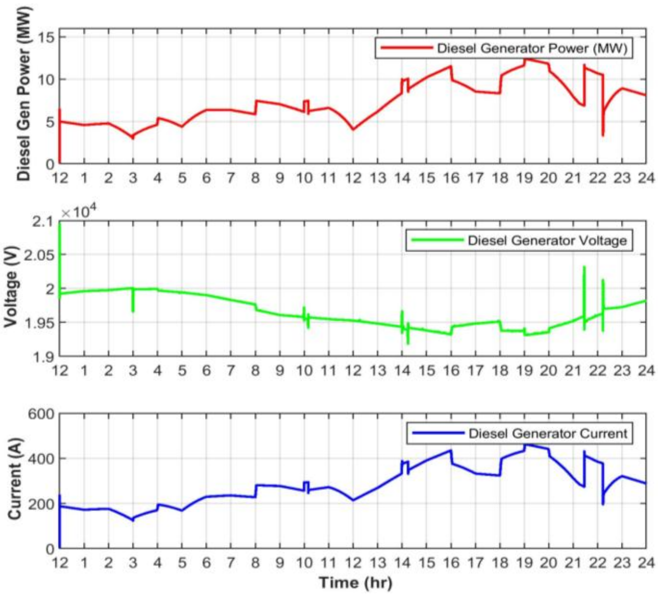

Fig -5: Diesel Generator Power, Voltage and Current Simulation Results

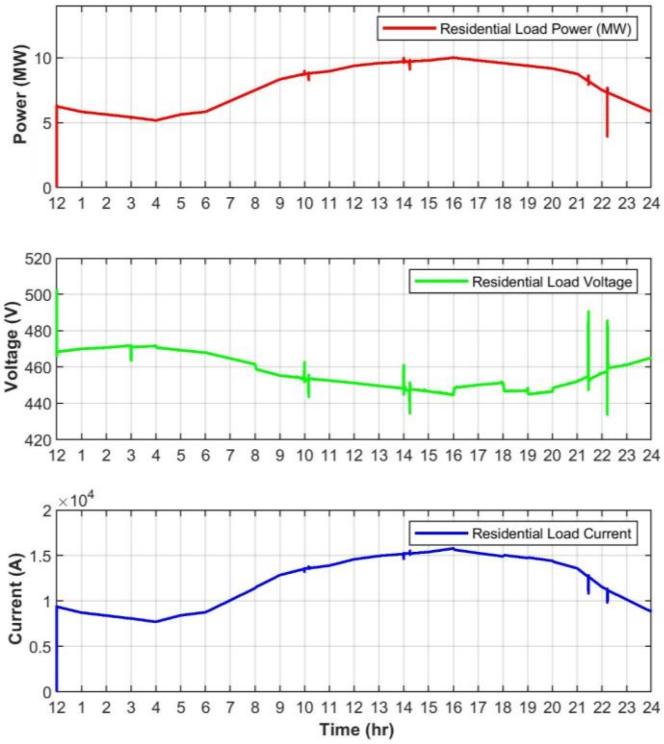

Fig -6: Residential Load Power, Current and Voltage Simulation Results

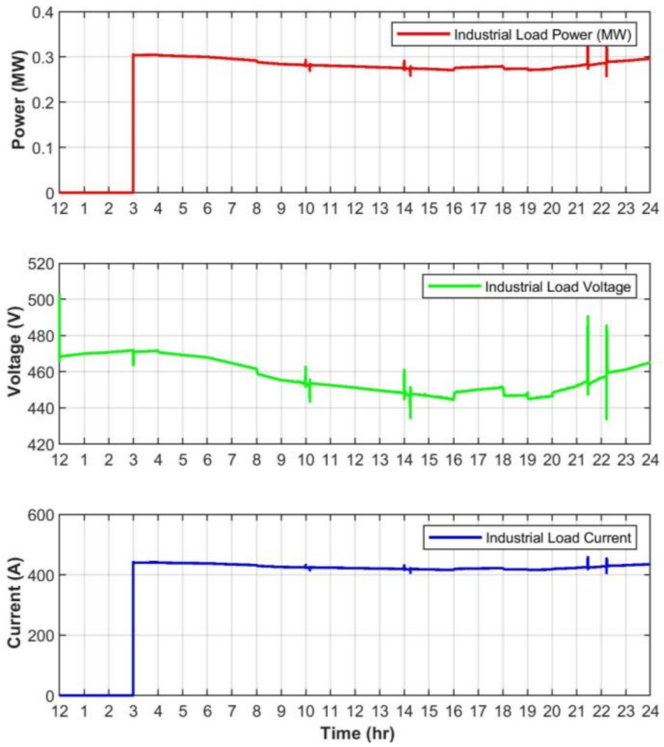

Fig -7: Residential Load Power, Current and Voltage Simulation Results

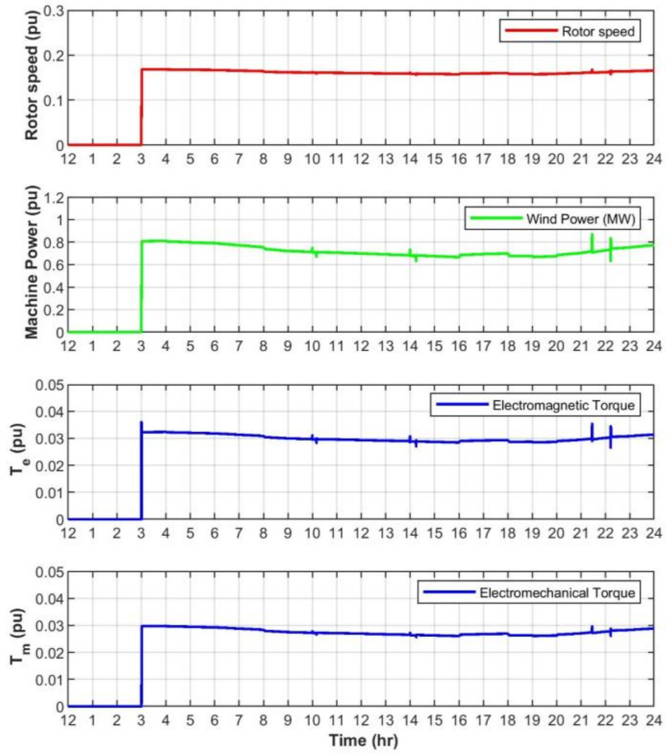

Fig -8: Industrial Load Asynchronous Machine Rotor Speed, Power, Electrical Torque and Mechanical Torque Simulation Results

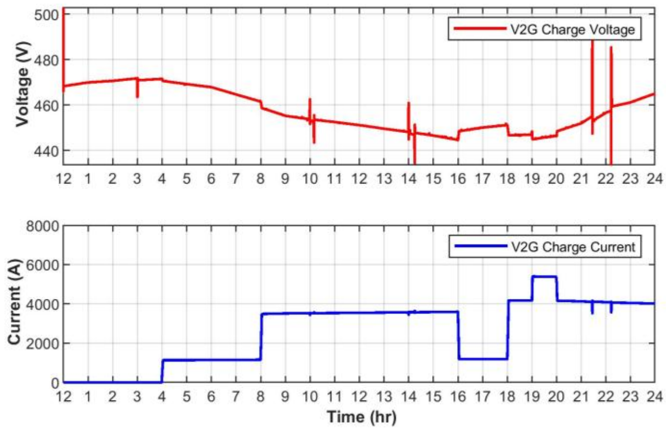

Fig -9: V2G Charging Voltage and Current Simulation Results

Figure 12 shows the combined plot of power from PV farm, wind farm, diesel generator, total power and load power. Load power is shown in yellow, total power in blue, diesel power in red, solar power in green and wind power in magenta.

During the hours 12 and 6 power output from the PV farm is zero and power generated from wind is less than 3 MW. During this period load demand increases as shown by yellow line so the wind farm is not able to fulfil that load demand alone, in this scenario diesel generator support the load demand and generate extra power required by the load. At 10 hr and 14 hr partial shedding effect take place. During this shedding effect power output from PV farms drops so to fulfil reduced power diesel power generate more power.

As wind speed exceeds the maximum wind value about 21.45 hr wind farm get trips as seen in the figure 12 by magenta line. Industrial load is turned on at 3 hr.

Figure 13 shows the grid frequency response. Several events occur during the complete 24 hr simulation time. First, industrial load is turned on at 3 hr. Second, partial shading effect-1 starts at 10 hr. Third, partial shading effect-2 starts at 14 hr. Fourth, wind farm interruption starts at 21.45 hr and resumed at 22.21 hr. Grid frequency is regulated by the cars which are in regulator mode.

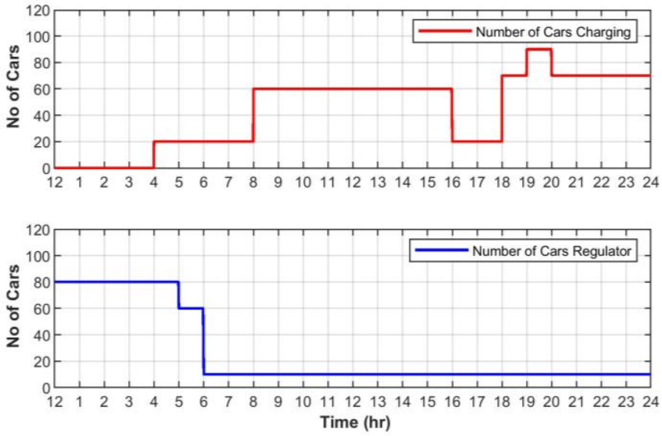

Fig -10: Number of Vehicles in Charging and Number of Vehicles in Regulation

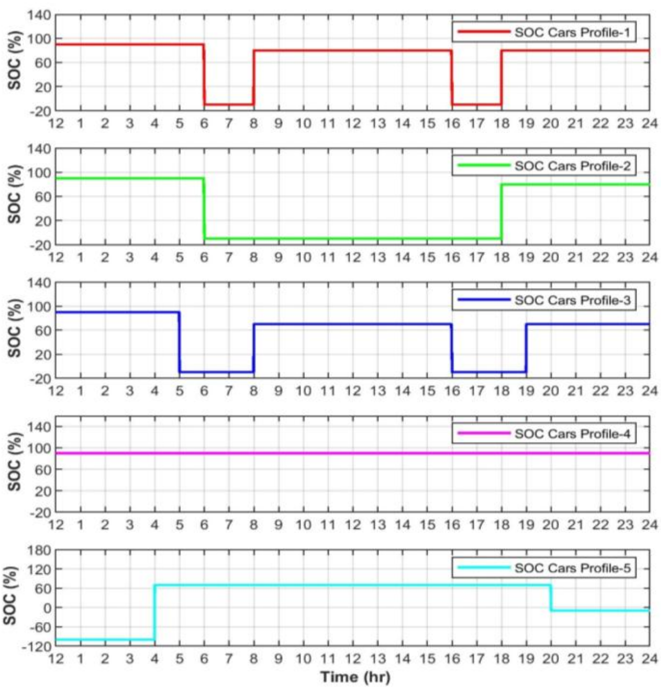

Fig -11: Car Profiles SOC Simulation Results

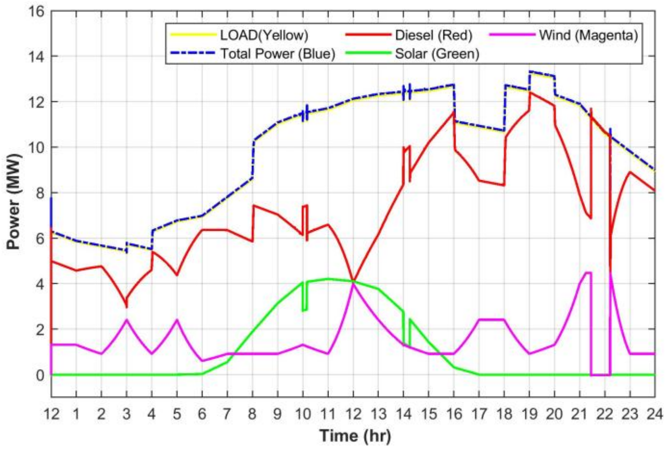

Fig -12: Combined Power Results

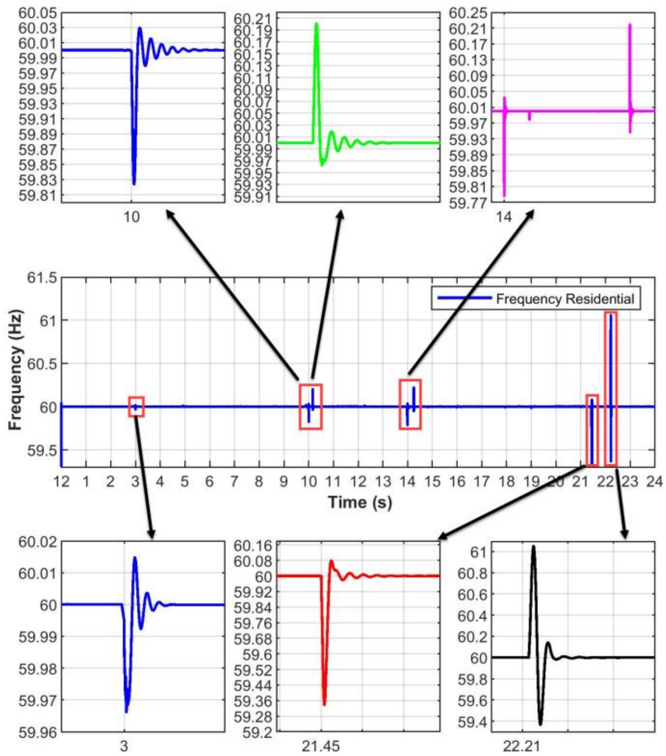

Fig -12: Grid Frequency Results

5. CONCLUSIONS

In in paper, we have analyzed V2G application for frequency regulation in micro grid with solar, wind and diesel power generation environment. Model is simulated for 24-Hr scenario and during simulation several event like partial shading effect at 10Hr and 14Hr are considered, industrial load is turned on at the 3Hr, wind farm disconnected at 21:45Hr due to over speed of wind are occurred. Results shows that V2G under regulation mode regulated the grid frequency in very effective manner and shows good dynamic performance. The complete model is successfully simulated in MATLAB/Simulink environment. In future, we will further study V2G application in large power system network for voltage and frequency regulation.

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