Protection of V2G System against the Faults with Self-Healing Capacity

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Abstract -According to the current scenario, EV's (Electric Vehicles) are combining vehicle engineering, electrical and control engineering in all way to overcome the environmental problems. Vehicle-to-Grid (V2G) technology is also playing a censorious role to balance the power on the generation and consumption side. During peak times, it adds the capacity to the electrical power grid without any need of industries and other power plants. Power continuity is already maintained directly or indirectly by keeping the record of battery status, throughout the day. On the other side, technical challenges and trends are also associated with the implementation of V2G system, which includes fault detection and its mitigation is one of the very serious tasks to handle. These disturbances are complicated and will increase in different components as their catching time is much more, finally power failure may cause the dangerous problems.In this paper, the protection of V2G system with the self-healing capacity with auto reclosing techniquenover against the symmetrical and unsymmetrical faults is presented. This will be the effective protection for V2G system as it takes the rapid action to any failure to progress its reliability and will maintain the voltage and transient stability also.

Keywords -Electrical Vehicles (EVs), Vehicle-to-Grid (V2G), Smart Grid (SG), Renewable Energy Sources (RES), Symmetrical Faults and Unsymmetrical Faults.

I. INTRODUCTION

At the present time, power industry is facing many challenges like increased power requirement, power loss at grid side, quality power and to overcome this, it is important duty to send power to the customers in a protected, authentic and justifiable manner. That's why, Europe and other countries are considering the Smart Grid (SG) is an important share of their national power policy [1]. Day by day SGs are having many developments to uphold the continuity of facilities and to enhance the reliability as it is directly linked to the accurateness of the system. Today, Vehicle-to-Grid (V2G) has named as the next generation, which uses the two-way communication for power and enhance the energy efficiency including the ecological benefits. V2G system is having the important features like bi-directional power flow, source and demand-side management, wide-area monitoring system, integration of Renewable Energy Sources (RES) into SG [2], predictive control of different renewable sources, proper load sharing and coordination between the sourcesetc.In spite of having these many advantages, it is facing the problem to continue energy flow without the interruptions through faults.Therefore, it is needed to know the origin of faults and also to forecast when a system fails, so that time taken will be reduced to back to its normal state.75–90% of faults are not permanent in nature.

A. Fault and its Classification

In general, afault is disorder to report something, which is not working properly or to be more precise an abnormal electric current in which, current exceeds the normal operating condition. Its identification must be quick, so that V2G system's self-healing ability can be fully utilized to perform the desired task and sustain the normal functions. If it will be prompt then synchronizing issues will be reduced and also, it is sufficient to avoid the complete network breakdown.Already a deep research has been done and is extra probable on categorization & identification of faults. In a broad way, it can be categorized as follows- physical device or component fault, communication fault and software or hardware fault.Some papers are classifying it as- incipient fault (creates fire and harmful effects), abrupt fault (produces power losses) and intermittent fault (for very less time but may leads to permanent failure). Some faults occur occasionally like transient faults due to lightning, persisting faults due to criminal intervention, faults due to sudden change in load and so on [3].

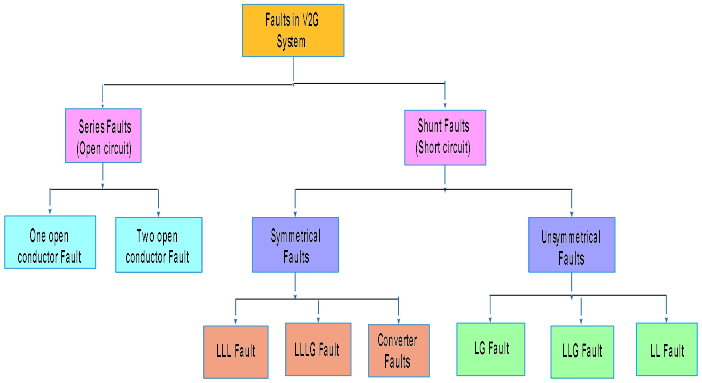


Figure 1. Faults Classification in V2G System

Power failure splits in two types- internal fault (at storage system) and external fault. External fault is of two types- series fault (because of open circuit or broken line conductors) and shunt fault (short circuit, because of contact of conductors with each other or contact with ground). Again, there are two types of shunt fault- symmetrical (a balanced fault) and unsymmetrical fault (an unbalanced fault) as shown in Figure 1. These faults can produce serious difficulties and everlasting harm to the system. Therefore, fault management and diagnosis by some protection solution is very important to continue the regular operation and guard the system components [4].

B. Protection Solution

The protection solution should be reliable, economical and able to give supreme protection to the system. Its idea and designing by default, separates the fault section quickly from the healthy part, without damaging the neighboring areas. Also, its smart automation function reestablishes power to the network parts, which are already in good condition. It must support the **self-healing** role, which is applied to the V2G system. Self-healing is one of the interesting features in which, the system is skilled to continue the power supply after any type of disturbances also. It is a wide concept which [5], enables automatic detection to avoid the false trips and the system recovery during a fault. Its actions are multi-objective to reestablish the system by their own as fast as possible and typically reconfigures the system within one to five minutes. For self-healing capacity automation, reclosers and fault circuit indicators plays an important role. In V2G system, it actually controls the dynamic bidirectional power flow and the fault growth in several components, which is already serious in terms of security and privacy concerns. If time to time fault diagnostics and upgradation is not undertaken, then it can cause uncertainties and other losses [6].

C. Literature Survey

According to [7], if generation capacity greatly exceeds the network capacity, then due to the network imbalance, it can have negative effects like lines losses, voltage rises, harmonics, network instability and faults etc. In [8], to identify and locate the faults in PDS (Power Distribution System), solution of IoT is projected. [9] proposed a fault analysis method, which is based on AC/DC hybrid microgrid simplified model. According to [10], the contribution of fault current depends on the DG type present in the system. Authors in [11], employ a fuzzy logic algorithm to

detect the faults in an unbalanced PDS. In this, they are neglecting the fault inception angle effect. [12], reviewed the Wavelet Transform (WT) to analyze the travelling waves and got the detailed coefficients for LG fault. In [13], authors analyzed the differential current in microgrid to sense the types of faults. In [14], unsymmetrical faults like LG and LL faults are noticed in microgrid by using zero and negative sequence components.However, all methods are offering the fault detection and the exact fault location in SGs, but they are not discussing about the faults in V2G system.

D. Paper Organization

This paper is organized in such a way that Section II is explaining about the sources, which are used in V2G system. Section III presents the methodology for the protection of V2G system along with the self-healing capacity. Simulation results and discussion part is in Section IV and conclusion along with the future scope in Section V.

II. V2G SYSTEM DESCRIPTION

V2G technology offers an intelligent way to balance the source and demand side for reliability to boost the system performance.Its concept is based on to deliver the power from EV battery to grid at peak hours. During the charging process, energy flow is from "Grid-to-Vehicle" and that energy is stored in EV batteries then used for driving purposes. Similarly, when grid's power demand is high then fully charged vehicles have the capability to feed that extra stored energy back to the network, which makes "Vehicle-to-Grid" i.e. bi-directional for the better energy management. The expansion in SGs because of increased power demand affects the coordination in V2G system including power electronic converters. Therefore, the protection schemes are becoming more significant and needs a fault management study to avoid power failures, false tripping etc. Finally, V2G fault protection has to give high importance both for safety and functionality reasons [15].

In this paper, proposed model consists of RES like Photo Voltaic (PV) farm and a wind farm which is associated with SG and Diesel Generator (DG). High and low power loads (industrial and residential loads) are also connected to the system [16]. A step-up and step-down transformer is provided in the system. The RES connected to the SG via transformer of 25 KV/25 KV and overall rating of the grid system is 25 KV having a frequency of 60 Hz. In the model, industrial load of 160 KW and residential load of 10 MW and both the loads are connected to the 25 KV/415 V transformer. Transformer is a fundamental component whose damage or failure causes significant economic and social injuries. In the end, a fleet of EVs system of 4 MW is connected to the network. This V2G is one of the solutions to provide continuous and stable power by integrating RES into the electrical network [17].

A. Wind System

This system is having the net output power of 5 MW with Wind Turbine (WT) and a synchronous generator is converting the wind output into required electrical energy. It is assumed that WT has a nominal speed of 13.5 m/sec and 15 m/sec a maximum wind speed. If high wind speed affects the frequency, gearbox, blades and WT reactive power, then chances of faults occurrence will be increased. In this system, the general faults are- Bearing faults (occurs in gearbox and main reason for WT failures) which is of two types- inside/outside race faults and ball faults. Stator, rotor faults (occur in generators, which producesunbalanced voltage, current, less average torque, excessiveheating) and Semiconductor device faults (related with the power electronics and electric control)

B. PV System

Proposed model is using 32 panels and total area of each panel is 8×10^4 Sq. m associated with the low voltage in SG. The number of cells is 60 in the panel and each cell is having the capacity of 0.6 Volts. The net supplied power by the solar panel is having the rating of 8 MW. This system is generating the maximum rated output by maintaining 100 $W/m^{2\ as}$ constant irradiation. On SG solar inverter is used to convert the solar power into AC power, which is compulsory for the grid connection [18]. A failure in a single cell affects the part of PV system, which gives the power losses. In PV panels some general faults are Cell faults- It is of three types,*open/short-circuited cells* (for cell disconnection), *hot-spot faults* (decreased cell current because of partially shading of panel) and *degeneration faults*

(if cell series resistance rises or cell shunt resistance reduces).Module faults- due to manufacturing defects and by-pass diode faults- due to an overheated diode [19].

C. Diesel Plant

SG accommodates local generating capacity like DG of 15 MW from which mechanical power is transferred to the salient pole synchronous generator (in which false tripping is common) generating 25 KV. DG installation improves the voltage and power quality along with economical profit to reduce the need of new transmission line. Non-conventional energy sources are connected to the DG as the distributed energy sources power must be matched with the load necessities.In synchronous generator, the most common fault is ground fault in stator windings, which decreases the performanceby voltage and current drops. If fault occurs in the protection zone, then power supply from DG will be stopped and disconnected. If cause is small then a minor fault occurs, which affects residential houses only, easy to repair and solved in few hours otherwise large-scale fault (cascading failure or blackout) affects a large area and will take some days to recover [20].

D. EV's for V2G Technology

Battery Electric Vehicles and Plug-in Hybrid Electric Vehicles, connect to power grid and sell the demand response services by V2G or G2V concept, which leads to reduce the consumption of fuel and pollution. 100 EV's are assumed in the main model, means 1:10 ratio in between cars and the households.If **battery** part is not concentrated then the chemical reaction, temperature etc. all such factors will definitely disturb the performance of battery during its usage and lack of battery life will restrict the EV's development too. Lithium-ion batteries used in large scales and is given special consideration these days to support energy storage, load flattening and frequency regulation. Battery management system is maintaining the charging and discharging record of the battery.

III. PROPOSED METHODOLOGY

To achieveself-healing capacity in V2G system, it needs advanced software (sensors, automatic controls), real-time datatransmissionto detect the problems, reconfigure the network to isolate and minimize the power output and impacts on the customers [21]. It reconfigures the Circuit Breakers (CBs), relays, load limits, controls the generator's output power andusuallyreconfigured within1-5 minutes by high bandwidth communication.

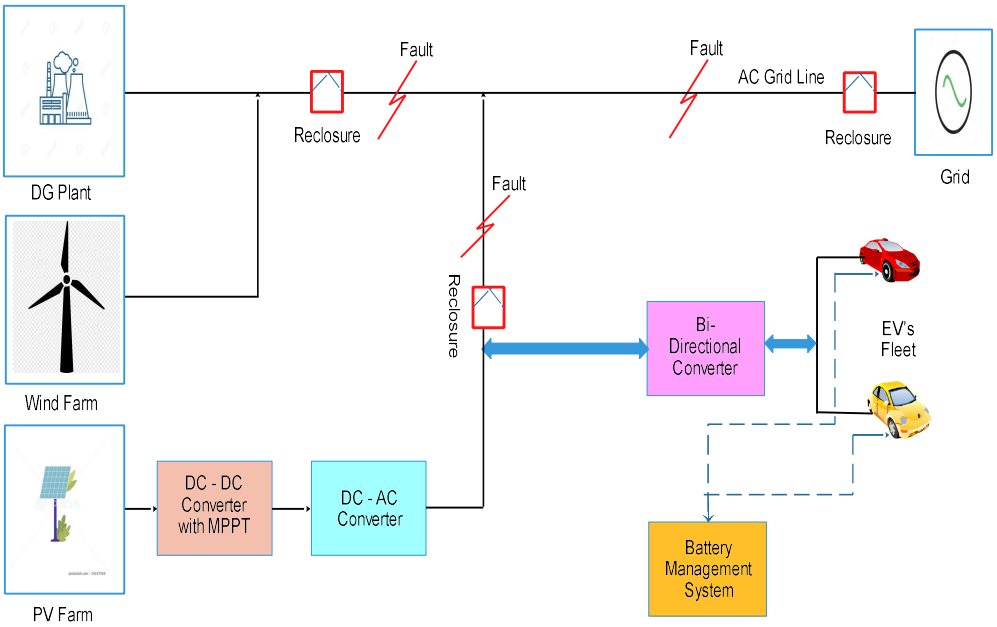


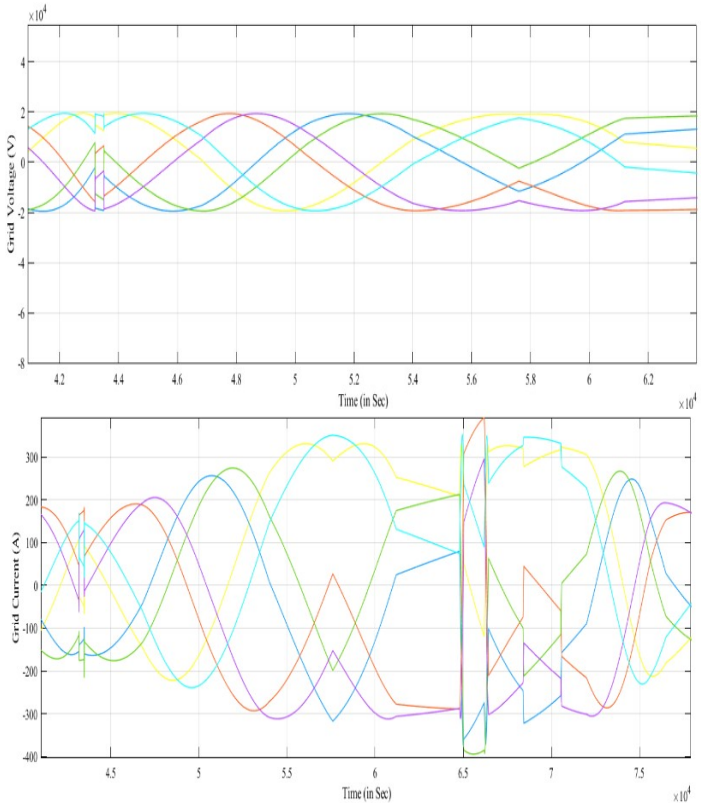
Figure 2. Protection of V2G System

In this, reclosing devices are mounted on distribution system to rapidly separate the feeder's damaged partto regenerate service for the customers as possible by an alternate source. It makes the necessary adjustments to

restoreitself without any human intervention successfully. The self-healing task is a multi-purposenon-linear optimization problem with many constraints and to solve this problem, advanced techniques like CB's auto reclosing and relay systems are developed. In SGs, the restoration problemis very advanced because it has two-way power flow mesh connectiontopology and also restricted capacity of Distributed Energy Resources (DER). If anerror occurs in the general grid, then CB opens and after a while it reconnects to the system to make sure thefault clearance. The proposed system is implemented with auto reclosing of CB's and relays, which are located on the grid side, source side and the load side, as shown in Figure 2.In the proposed V2G system, if fault occurs whether symmetrical or unsymmetrical, it is detected and activated within the specified time by using the reclosing of CB's and relay systems. This technique gives the fast response, high accuracy in clearing the faults and the reliable system.

IV. RESULTS AND DISCUSSION

By using MATLAB/Simulink model, the simulation results are done for the proposed V2G system to analyze the self-healing capacity against the various symmetrical and unsymmetrical faults. The proposed system parameters are shown in Table I. The Figure.3. and Figure 4. shows the simulation results for LLL and LLLG fault respectively. And Figure 5. and Figure 6. shows the results for LG and LL fault. From results, the various faults are created and cleared in two intervals of time, which is at 4.3 sec and at 6.5 sec by auto-reclosing switch during a specified time. The grid voltage, grid current and EV's battery voltage all are shown for all types of faults. From the results it is observed that grid voltage and EV's battery voltage are not impact on grid fault current. This will enhance the system stability and provides the self-healing capacity over different types of faults. On the basis of simulation results because of faults, transients in the system are easily recognized and distinguished from the regular process. Peak fault current difference has no effect on the grid performance and other energy sources.



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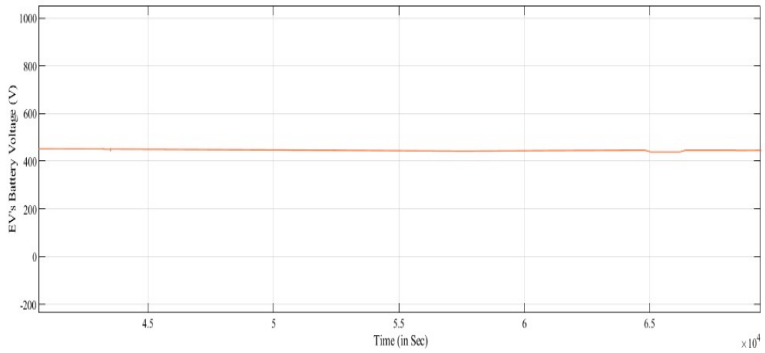
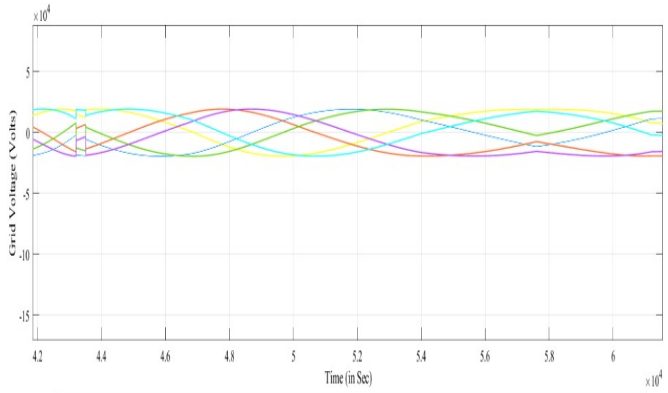
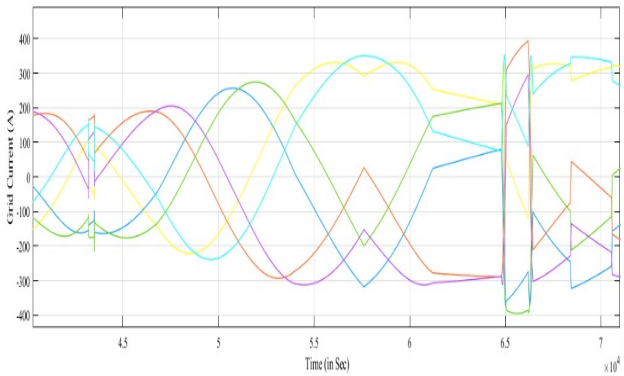


(c)

Figure 3. (a) Grid Voltage (b) Grid Current and (c) EV's battery voltage due to L-L-L Fault





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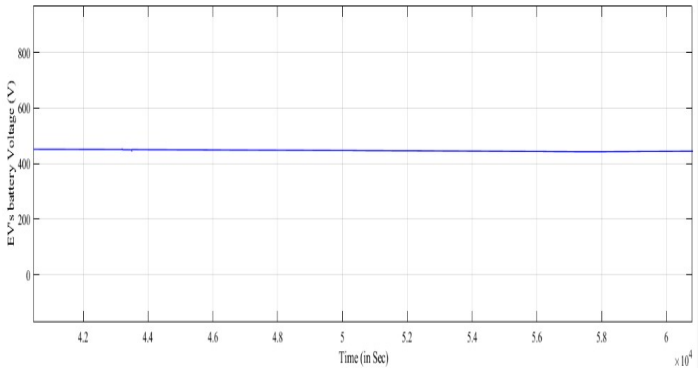

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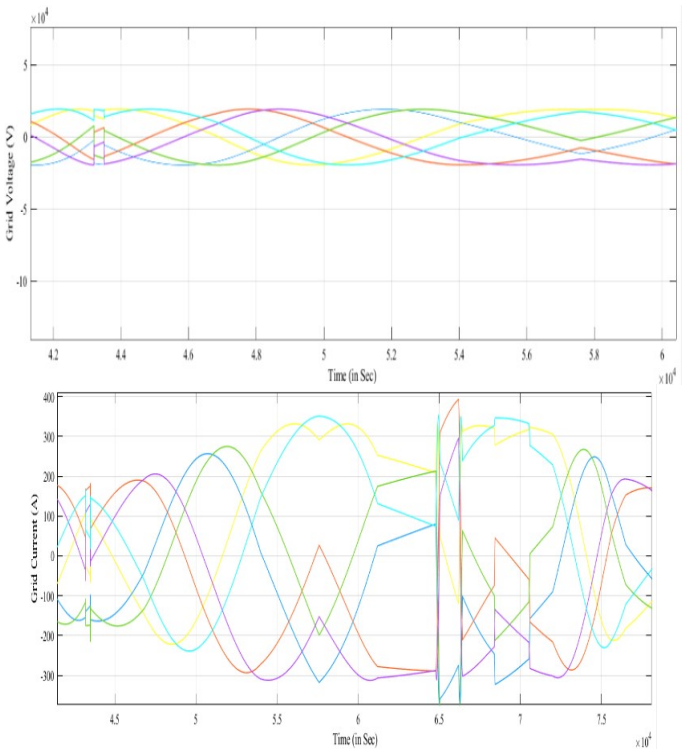
Figure 4. (a) Grid Voltage (b) Grid Current and (c) EV's battery voltage due to L-L-L-G Fault



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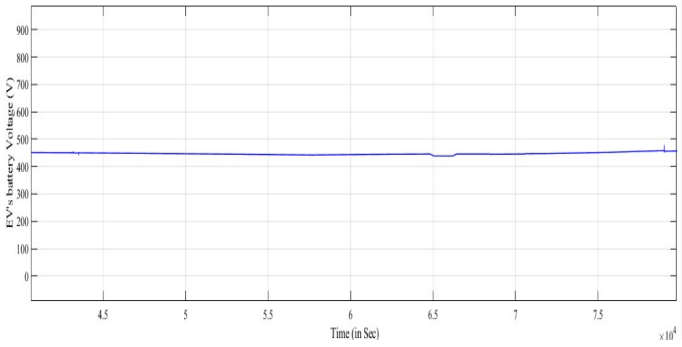

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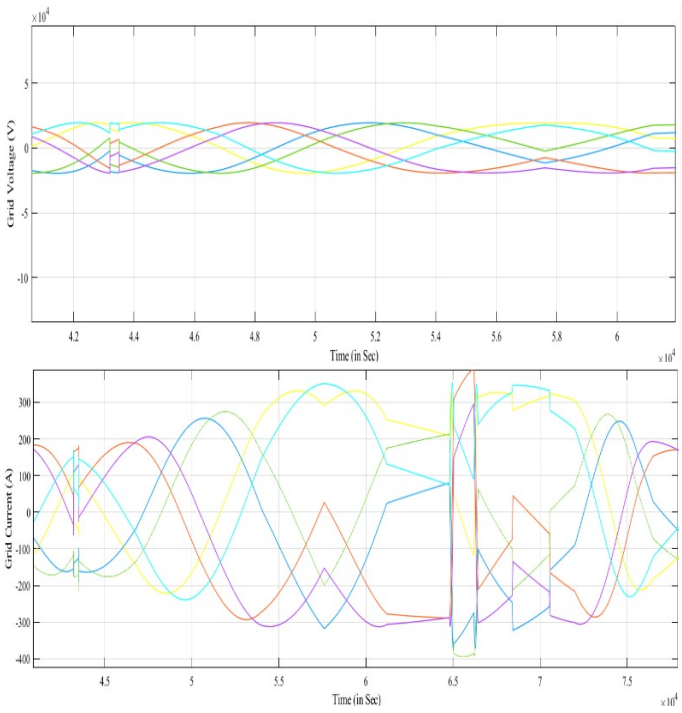
Figure 5. (a) Grid Voltage (b) Grid Current and (c) EV's battery voltage due to L-G Fault



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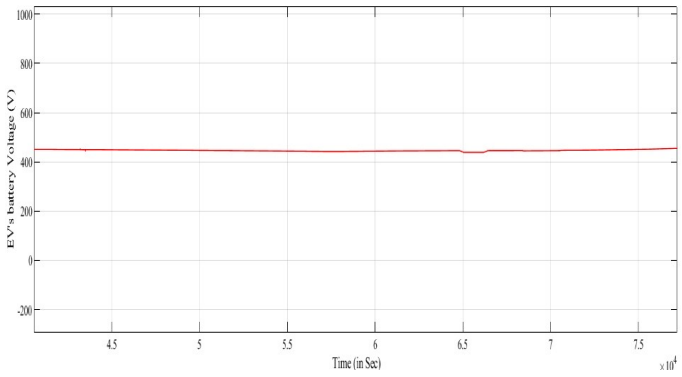

(c)

Figure 6. (a) Grid Voltage (b) Grid Current and (c) EV's battery voltage due to L-L Fault

Table -1 System Parameters

Type of Source	Rated Power (in MW)	Voltage (in kV)
Diesel Generator	**15**	**25**
Wind Farm	**05**	**0.575**
PV Farm	**08**	**0.6**
EV's fleet	**40**	**0.45**
Domestic	**10**	**0.6**
Industrial Load	**1**	**0.6**

V. CONCLUSIONS

In V2G system, it is observed that fault analysis and its clearance is important for the stability of the network. Now, its protection becomes a challenge as fault occurs at any point, because of natural cause, operational error, cyber or physical attack. This paper presents the fault classification and analysis of self-healing capacity against the symmetrical and unsymmetrical faults and their causes, which is affecting the V2G system. This protection solution is ideally concentrating on both fault detection and its location. It is restoring the power in less time even after the fault occurrence. From the given software, obtained simulation results verifies the self-healing capacity effectiveness in recent V2G structure with fast response. In spite of having many approaches, there are still some faults, which needs a little more attention to really make the present V2G system more up-to-date, the proposed method gives better performance against the major faults within the short duration of time.

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