PERFORMANCE ANALYSIS OF FUZZY LOGIC CONTROLLER FED EV CHARGING STATION WITH FRT CAPABILITY

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ABSTRACT:

All future power networks will inevitably have to handle electrical vehicles (EVs). The electric vehicle (EV) charging system must have a high-quality power source in order to operate properly. Still, among the major problems with the distribution system is the voltage quality. Analysis of the impacts is the goal. The effects of voltage fluctuations on the batteries and charging systems of electric vehicles (EVs) and provides a fault ride-through capability (FRTC) to enhance voltage quality. This article focuses on the DC-DC converter and the three-phase regulated rectifier, which are key components of the charging system's architecture. Lithium-ion battery technology is used in the design of the electric vehicle (EV) battery pack. The FRTC system's core components, a dynamic voltage restorer (DVR) and fuzzy logic, were created to improve voltage quality. Finding out how key voltage sag levels affect batteries and charging systems is the aim of this research. The efficacy of the suggested electric vehicle charging station (EVCS) the investigation encompassed voltage sags of 30%, 60%, and 90% by using MATLAB/Simulink platform.

Key words —distribution grid, voltage sag, fault ride-through capability (FRTC), electric vehicle (EV) charger, and power quality.

I.NTRODUCTION:

Electrical Electrical charging stations and vehicles (EVs) need high-quality power to operate properly. The grid supply is, however, vulnerable to a number of power quality problems in real life. The distribution grid's main problem is low voltage quality, which is caused by electric motors and abrupt fluctuations in loadBeginning, a distribution grid malfunction, power line mishaps, and transformer energization. The charging profile of an electric vehicle and the life cycle of its battery are directly impacted by low voltage. Electric vehicles (EVs) are increasingly being recognized as a significant challenge for future power systems.

Fault ride through (FRT), also known as under-voltage ride through (UVRT) or low voltage ride through (LVRT) in electrical power engineering, refers to an electric generator's capacity to maintain connectivity during brief drops in the electric network voltage (voltage sag). In order to stop a short circuit at the HV or EHV level from resulting in a widespread loss of generation, it is necessary at the distribution level (wind parks, PV systems, distributed cogeneration, etc.). Uninterruptible power supplies (UPS) or capacitor banks are frequently used to address similar requirements for essential loads, such as computer systems and industrial processes, in order to supply make-up power during these situations.

The incorporation of electric vehicle There are significant effects on power quality when electric vehicle charging stations (EVCSs) are widely integrated into the distribution system. The occurrence of a distribution grid malfunction, power line mishaps, and transformer activation [2]. In recent times, there has been a significant emphasis in scholarly study on examining the effects when using the distribution grid to charge electric vehicles (EVs). The examination carried out in [3] analysed how plug-in electric cars (EVs) affect the power distribution infrastructure.

The article [4] provides a comprehensive examination of power converter topologies, battery charging control systems, and the diverse effects of electric vehicle electricity-generating units (EVs) on the grid. The article examines the economic, environmental, and power network implications, as well as the diverse charging standards associated with electric vehicles (EVs). The assessment conducted in reference [5] evaluates the effects on distribution transformer overload, ageing, and voltage quality of plug-in hybrid electric cars (EVs).

Electric vehicle (EV) batteries have the capability to either at private residences or at charging stations that are open to the public. The interplay between the charger and the grid is of utmost importance and necessitates meticulous oversight. The charging time for an electric vehicle (EV) battery can extend up to a maximum of 8 hours . The duration of charging is contingent upon the battery's capacity and the power output of the charger employed. Consequently, the charger has the potential to remain joined the power grid for a period of time that approximately one-third of the day. According to the manufacturers of electric vehicle (EV) chargers, a crucial factor in achieving The key to the mass use of electric vehicles is the creation of converters that possess the ability to endure grid disturbances .

Determining power electronics-based energy resources' fault ride-through criteria. It is important to note, nevertheless, that there isn't currently specific standards pertaining to electric vehicle (EV) battery chargers. Voltage sags interfere with chargers' regular operation, and different charger types have varying degrees of resistance to voltage sags. Based on the voltage sag, a fuzzy controller is used to manage the injection value of voltage during a malfunction in DVR.

II. Proposed Methodology:

The literature frequently proposes the implementation of a fault ride-through capability (FRTC) system to improve voltage quality in a range of applications, including wind, solar, and hybrid energy storage systems within the distribution grid. Fault ride-through capability (FRTC) is commonly attained by utilizing several devices such as the dynamic voltage restorer (DVR), static VAR compensator, crowbar, and fault current limiter (FCL). In a previous study [6], a DVR was employed to improve the voltage quality and address the phase jump concerns associated with the sensitive load. In this paper, the authors examine the effects of voltage sag on adjustable speed drives and provide a solution to alleviate these effects using the enhanced synchronous reference frame (SRF) theory-based dynamic voltage restorer (DVR). The DVR is employed in reference [7] to enhance the Fault Ride Through Capability (FRTC) of the wind energy conversion system based on the doubly fed induction generator. The utilization of superconducting magnetic energy storage-based dynamic voltage restorer (DVR) and superconducting fault current limiter (FCL) is employed for the purpose of controlling the transient voltage fluctuations inside the distribution grid.

The utilization of FRTC is employed in reference [8] to circumvent the submodules responsible for switch failure. The offshore wind energy system described in reference [9] incorporates an upgraded capacity for low-voltage ride-through, specifically designed for permanent magnet synchronous generators. The Fault Ride Through Capability (FRTC) of a wind energy system is improved through the utilization of an on-load tap changer, as stated in reference [10]. The utilization of the hybrid superconducting Current Limiter for Faults (FCL) has been implemented [11] to improve the performance of electrical vehicles (EV'S). The results gained from the experiment are contrasted with the crowbar method and distributed static compensator. Among the many strategies considered, it can be concluded that the FUZZY-DVR-FRTC system exhibits superior performance in terms of enhancing voltage quality.

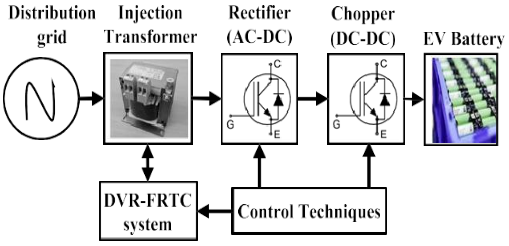


Fig.1 schematic diagram of proposed EVCS

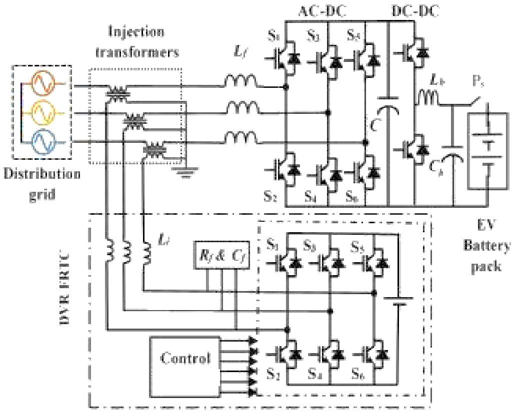


Fig.2 circuit diagram of proposed EVCS

Listed below are this article's main contributions. :

1) A study has been conducted on the effects the cause of voltage sag in EV charging infrastructure and batteries.

2) A FRTC (Ride Through Fault Capability) system based on DVR (Dynamic Voltage Restorer) has been developed specifically for EV charging systems.

3) This system offers a solution to mitigate the adverse effects of sag in grid voltage on batteries and EV charging devices .

4) The purpose of this technology is to safeguard the EV charging infrastructure and batteries by mitigating voltage sag's negative impacts.

5) The assessing system effectively maintains steady operation by managing the load voltage, even in the event of a significant voltage sag in the distribution grid.

Figure 1 illustrates the comprehensive circuit diagram of the anticipated charging station for electric vehicles (EVCS).

III. CONTROL TECHNIQUE:

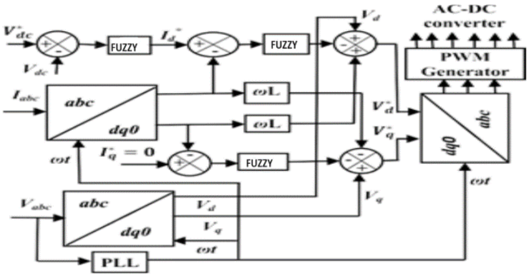


Fig.3: rectifier control strategy

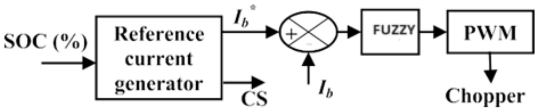


Fig.4: chopper control strategy

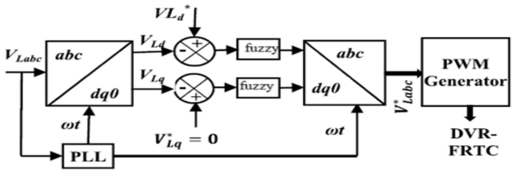


Fig.5: Control method for the DVR-FRTC system

The regulated rectifier and the chopper design the EV charger. The utility grid is connected to the rectifier input via the inductive filter. Both sufficient dynamic control and minimal switching losses should be avoided by having the rectifier output voltage set at a greater level. Equation (1) can be used to estimate the dc voltage.

$$V_{dc} = \frac{2\sqrt{2}V_{L-L}}{\sqrt{3}\,m} \text{ --------(1)}$$

where the line voltage is VL−L and the modulation index is m. In order to prevent the overmodulation effect, m is adjusted to 0.9 and the VL−L is taken to be 415 V. Vdc is therefore determined to be 752 V and selected to be 750 V.

A potential Distribution Flexible AC Transmission System (D-FACTS) tool that is frequently used to address issues with non-standard voltage, current, or frequency in the distribution grid is the Dynamic Voltage Restorer (DVR).It ensures a steady load voltage and maintains the voltage profile by injecting voltages into the distribution line. A DC power supply and an inverter with an injection transformer make up a DVR unit. are produced via the pulse width modulation method for the inverter.

The FRTC system, which is based on a DVR, primarily consists of several key components. These include ripple filter, injection transformer, dc voltage source, interface inductor, and three-phase voltage-source converter. This determines the power rating (VA) of the DVR's injection transformer and voltage-source converter.

$$S_{DVR} = V_{VSC} * I_{VSC}\text{------}(2)$$

where Vvsc and Ivsc are the voltage and current ratings of the voltage-source converter. The following formula can be used to determine Vvsc for the load with unity power factor. :

$$V_{VSC} = \sqrt{V_r^2 - V_a^2} - - - (3)$$

where Va is the actual source voltage during sag and Vr is the rated source voltage.

The DVR's ripple current is used to estimate the interface inductor (Li), which is expressed as follows for the voltage-source converter of the DVR. :

$$L_i = t_r * 0.866 * m_D * \frac{V_{DC}}{6 * a * f_{Ds} * \Delta I_r} - - - (4)$$

where VDC is the DVR dc-link voltage, a f is the overloading factor, fDs is the DVR switching frequency, I r is the ripple current, and tr is the injection transformer turns ratio. The DVR's ripple filter can be approximated by

$$f_{RF} = \frac{1}{2 * \pi * R_f * C_f} - - - - - - (5)$$

where f_{RF}, R_f, and C_f are, in that order, the resistance, capacitance, and ripple filter frequency.

This study employs Voltage Oriented Control (VOC) for the purpose of rectifier control. VOC relies on the implementation of coordinate transformations between the stationary α–β and synchronous rotating d-q reference framework. This feature ensures rapid and responsive transient response as well as optimal performance in continuous operation. The last execution of the framework in VOC is heavily dependent on the existing control strategies employed within the control loops.

This approach uses an outside loop to control voltage and an inner loop to control current. The following equation is used to convert the current and voltage's "abc" coordinates into "dq0" coordinates:

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin(\omega t) & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos(\omega t) & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} * \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \text{---}(6)$$

The reference d-axis current is determined by feeding the output dc voltage error via a fuzzy controller, while the reference q-axis current is taken to be zero. .

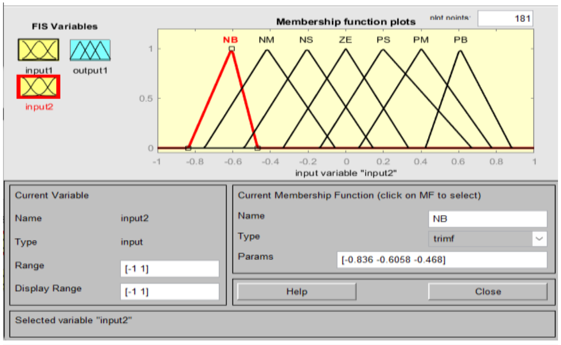
Subsequently, the reference voltages in the "abc" coordinate system is created from the "dq0" coordinate system. using equation (6). These resulting voltages are then employed in the rectifier switches' gating signals are produced by the pulse width modulation (PWM) generator.

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin(\omega t) & \cos(\omega t) & 1 \\ \sin\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t - \frac{2\pi}{3}\right) & 1 \\ \sin\left(\omega t + \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) & 1 \end{bmatrix} * \begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} \text{---}(7)$$

3.2 FUZZY LOGIC CONTROLLER:

In noisy and fluctuating situations, PI, although being a classic controller, performs poorly. Excessive integral actions can cause overshoots in many situations, and unnecessary proportional actions can cause unsteady output in others.

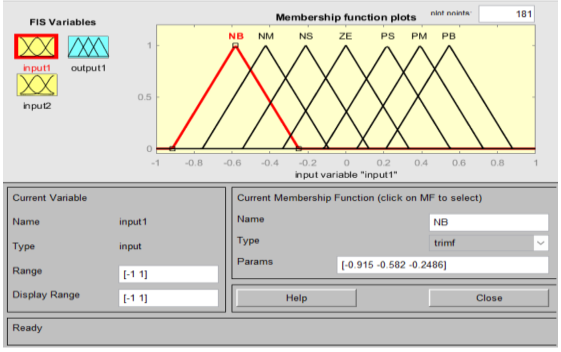
Fuzzy Logic Control (FLC) is a control system in which the output that is produced depends on the input's present state and any changes that occur in it. A control system called fuzzy logic control (FLC) bases its net output on both the input's initial state and any subsequent changes to that state. Therefore, in contrast to a PI controller, fuzzy control produces more accurate voltage restoration that is as near to nominal values as possible. Therefore, fuzzy control demonstrates superior performance in accurately restoring voltage to nominal values compared to a PI controller. FLC consists of two input membership functions (MFs)—that is, the error voltage and its variation— .



Current Variable
Name input2
Type input
Range [-1 1]
Display Range [-1 1]

Current Membership Function (click on MF to select)
Name NB
Type trimf
Params [-0.836 -0.6058 -0.468]

Selected variable "input2"



Current Variable
Name input1
Type input
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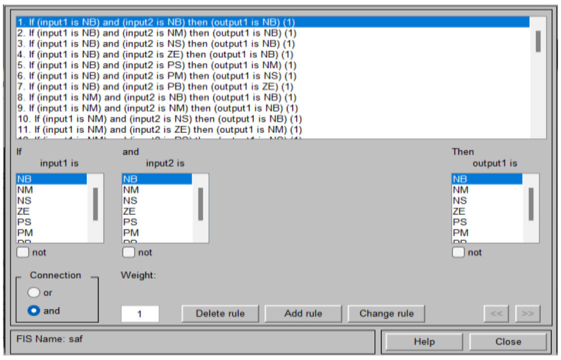
Current Membership Function (click on MF to select)
Name NB
Type trimf
Params [-0.915 -0.582 -0.2486]

Ready



1. If (input1 is NB) and (input2 is NB) then (output1 is NB) (1)
2. If (input1 is NB) and (input2 is NM) then (output1 is NB) (1)
3. If (input1 is NB) and (input2 is NS) then (output1 is NB) (1)
4. If (input1 is NB) and (input2 is ZE) then (output1 is NB) (1)
5. If (input1 is NB) and (input2 is PS) then (output1 is NM) (1)
6. If (input1 is NB) and (input2 is PM) then (output1 is NS) (1)
7. If (input1 is NB) and (input2 is PB) then (output1 is ZE) (1)
8. If (input1 is NM) and (input2 is NB) then (output1 is NB) (1)
9. If (input1 is NM) and (input2 is NM) then (output1 is NB) (1)
10. If (input1 is NM) and (input2 is NS) then (output1 is NB) (1)
11. If (input1 is NM) and (input2 is ZE) then (output1 is NM) (1)

Weight: 1

FIS Name: saf

SYSTEM PARAMETERS:

Parameter	Symbol	value
Grid voltage	V_S	415 V (ph-ph)
Grid frequency	F	50 Hz
Filter inductor	L_S	5 mH
Filter capacitor	C	3300 µF
DC output voltage	V_{dc}	750 V
Chopper capacitor	C_b	50 µF
Chopper inductor	L_b	4 mH
Battery nominal voltage	V_0	360 V
Battery capacity	Q	66.2 Ah
Switching frequency	f_S	10 kHz
Interfacing inductor	L_i	3 mH
Ripple filter	R_f ,C_f	5 Ω,30 µF

IV. SIMULATION RESULTS ,DESIGN AND DISCUSSION:

The MATLAB/Simulink platform is used to model the suggested DVR-FRTC integrated EVCS. The effectiveness of the EVCS is examined for varying sag levels, including thirty, sixty, and ninety percent, both with and without DVR-FRTC and fuzzy.

4.1 Performance analysis of the EVCS without-DVR-FRTC

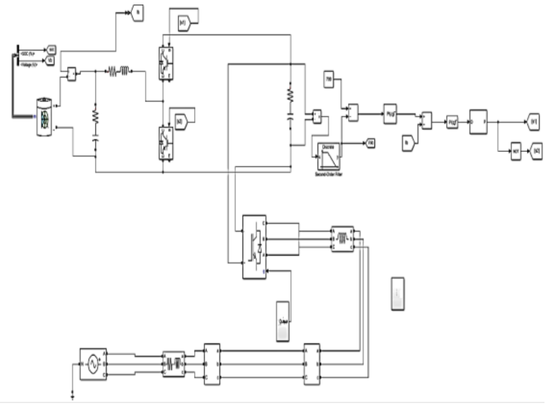


Fig 6: simulation diagram of Without DVR-FRTC

Investigations are conducted into the 30 percent, 60 percent, and 90 percent sags of the EVCS's performance without DVR-FRTC. .

Figure 7 shows the features of the performance at 30 percent sag. The grid voltage drops from 0.15 to 0.25 s, causing a 30% sag. Due to the lack of the DVR-FRTC system, there is an injecting voltage of zero. The load voltage therefore experiences the same sag. . On the other hand, the rectifier generates the predetermined DC voltage output. As a result, the system runs in a stable manner. Fig. 8 shows the corresponding battery properties.

When the state of charge (SOC) falls within the range of 20% to 80%, the charging current is determined to be 33.5 A. When the charge state (SOC) reaches 80%, the charging current is decreased to 23.5 A. Upon reaching a state of charge (SOC) of 90%, the charging current undergoes a subsequent reduction to a value of 13.5 A. When the state of charge (SOC) of the battery reaches 100the control signal (CS) changes from a high state to a low state, representing a percent change. To prevent the battery from being overcharged, it therefore triggers the safety switch (Ps). . Figure 6 depicts the performance parameters observed when the sag is set at 60%. The occurrence of voltage sag is observed at a time of 0.15 seconds and is afterwards resolved at a time of 0.25 seconds. The operational state of the system remains stable until the occurrence of a voltage sag, at which point it transitions into an unstable mode if the magnitude of the sag exceeds the critical threshold. The rectifier is incapable of effectively managing the significant decrease in voltage. Consequently, the direct current (DC) output voltage exhibits instability.

Fig. 9 shows the performance characteristics at 60 percent sag. Between 0.15 and 0.25 seconds, the voltage sag is formed and cleared. Before the sag is formed, the system operates in a stable mode; once the voltage sag exceeds the critical value, the system enters an unstable mode. There is a crucial voltage sag that the rectifier cannot manage. The dc output voltage is therefore unsteady. Furthermore, even once the sag is cleared, the system cannot return to its usual functioning mode. That influences the battery's properties as a result. During the 60% voltage sag condition, as seen in Fig. 10, there is fluctuations in the battery voltage, current, and state of charge.

The performance parameters of the EVCS at 90% voltage sag without FRTC. Figure 11 illustrates how the voltage sag is followed by the dc output voltage entering abnormal mode. There is no injection voltage in the event that there is no FRTC system. It has a direct impact on the voltage, current, and SOC. Fig. 12 displays the corresponding battery properties. .

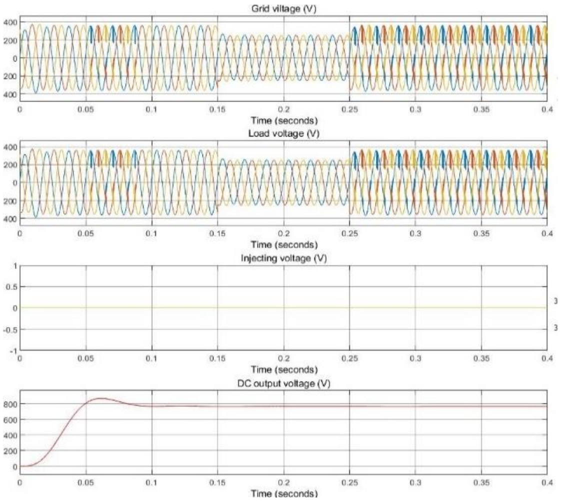


Fig.7: Performance characteristics without FRTC at 30% sag.

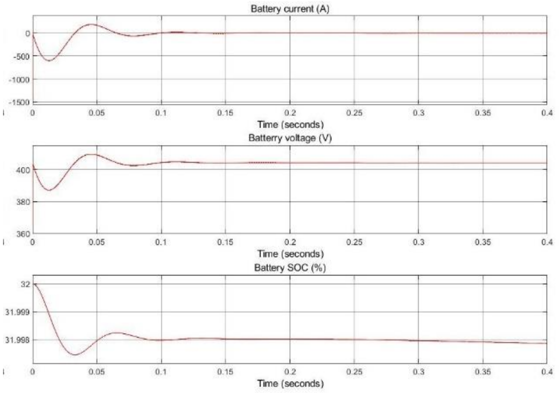


Fig.8: Battery characteristics without FRTC at 30% sag.

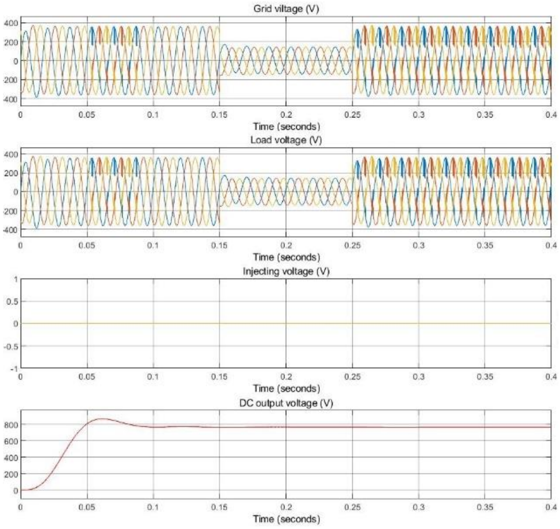


Fig.9: Performance characteristics without FRTC at 60% sag.

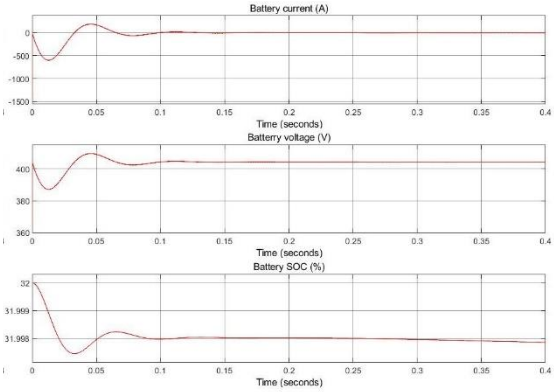


Fig.10: Battery characteristics without FRTC at 60% sag.

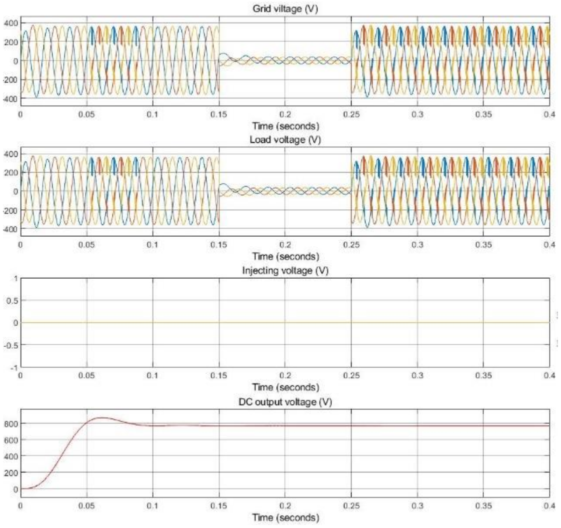


Fig.11: Performance characteristics without FRTC at 90% sag.

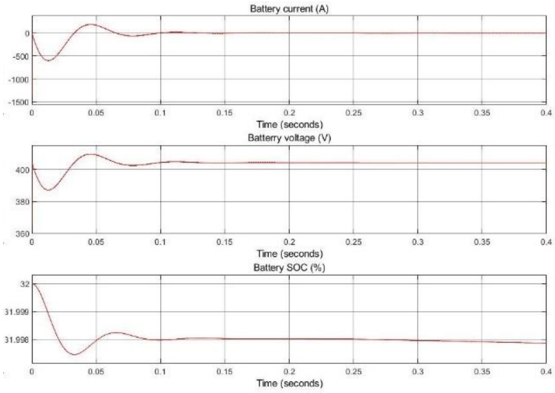


Fig.12: Battery characteristics without FRTC at 90% sag.

4.2 Performance analysis of With DVR-FRTC:

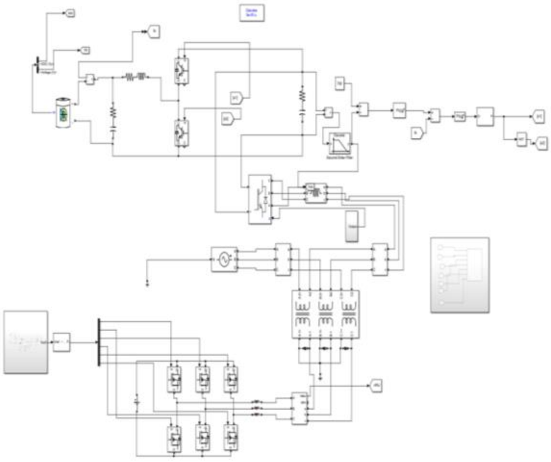


Fig.13:Simulation diagram of with DVR-FRTC

The effectiveness of the DVR-FRTC-equipped EVCS is examined at three distinct voltage sag percentages: thirty, sixty, and ninety percent. Fig. 14 depicts the 30 percent sag performance characteristics. The grid voltage experiences a sag at 0.15 s. The voltage is injected into the load by the DVR-FRTC system during this time. As a result, the load voltage is kept at the reference value. The rectifier further generated the predetermined dc output voltage. As a result, the system runs in a stable manner. Fig. 15 shows the battery characteristics for this operation mode. .

In Figure 16, the DVR-FRTC system's performance characteristics during the 60 percent voltage sag are shown. The DVR-FRTC initiates the voltage injection in phase with the load voltage during the voltage sag period." . As a result, the load voltage is controlled to maintain the system's stable operating mode at its rated value. In addition, a nominal value is maintained for the rectifier's output voltage. The battery voltage, current, and state of charge (SOC) are all kept at their nominal values even when there is a 60% voltage sag, as illustrated in Figure 17.

At 90% voltage sag, EVCS performance parameters with FRTC are displayed in Fig. 18. The load voltage in this case adheres to the conventional value. since the voltage is injected by the DVR-FRTC system when there is a voltage sag. Because of this, the predetermined value of the DC output voltage is maintained. The battery's voltage, current, and state of charge are maintained at the proper values. Fig. 19 lists this mode's battery characteristics.

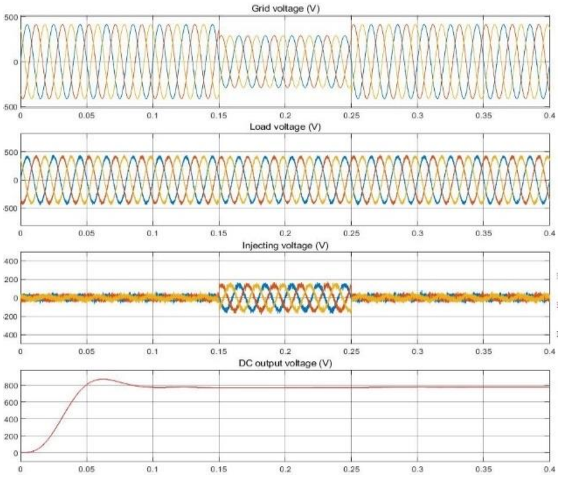


Fig 14: Performance characteristics With DVR-FRTC at 30% sag

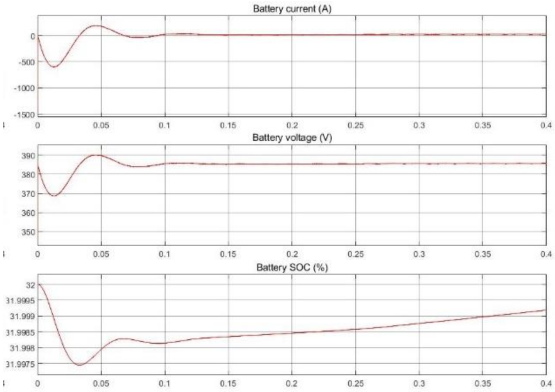


Fig 15: Battery characteristics With DVR-FRTC at 30% sag

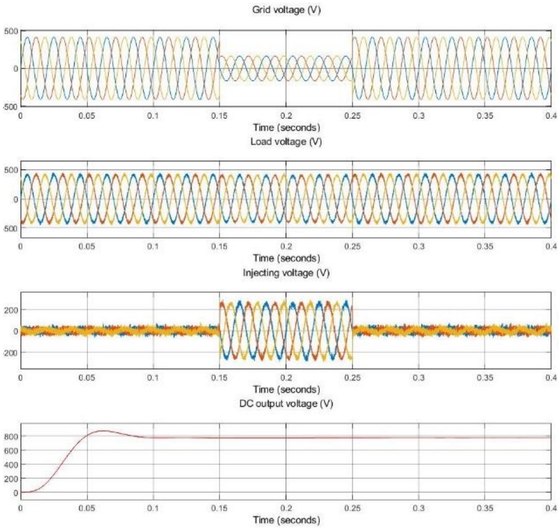


Fig 16: Performance characteristics With DVR-FRTC at 60% sag

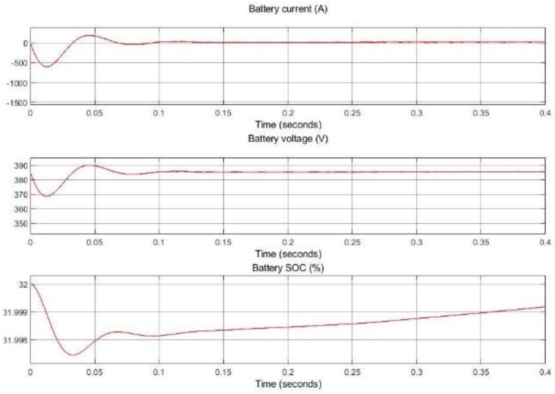


Fig 17: Battery characteristics with DVR-FRTC at 60% sag

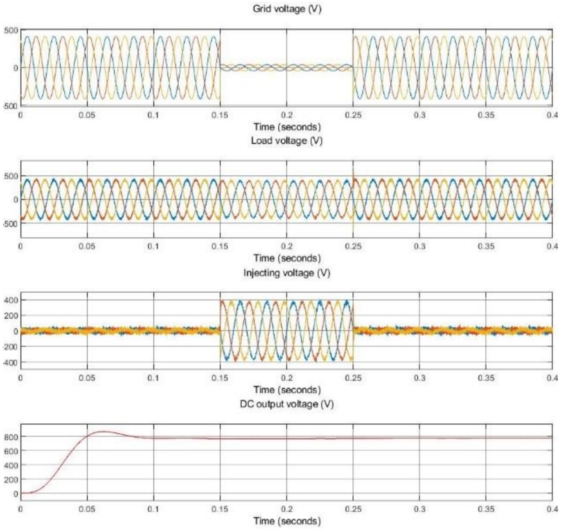


Fig 18: Performance characteristics With DVR-FRTC at 90% sag

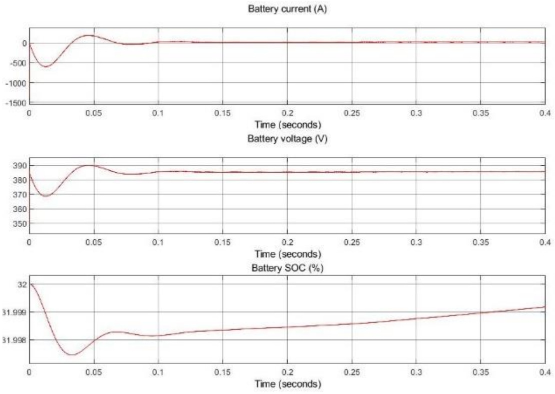


Fig 19: Battery characteristics with DVR-FRTC at 90% sag

4.3 Performance Investigation with Fuzzy-DVR-FRTC

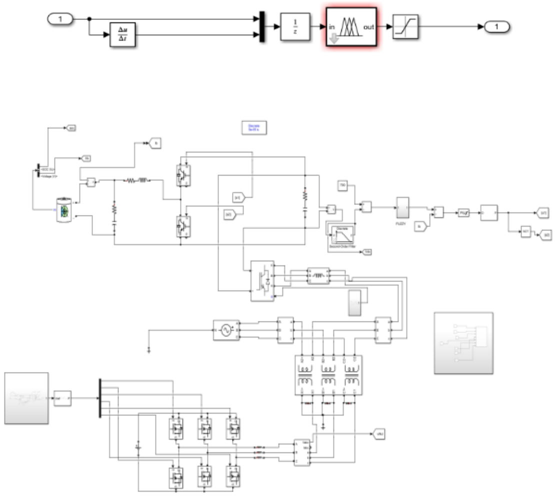


Fig.20: Simulation diagram of with Fuzzy DVR-FRTC

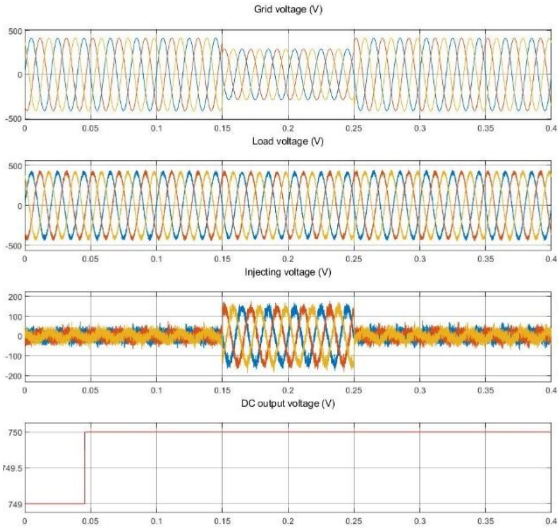


Fig 21: Performance characteristics with Fuzzy at 30% sag

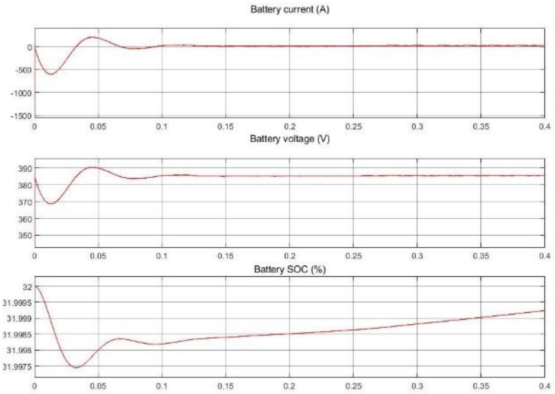


Fig 22: Battery characteristics with Fuzzy at 30% sag

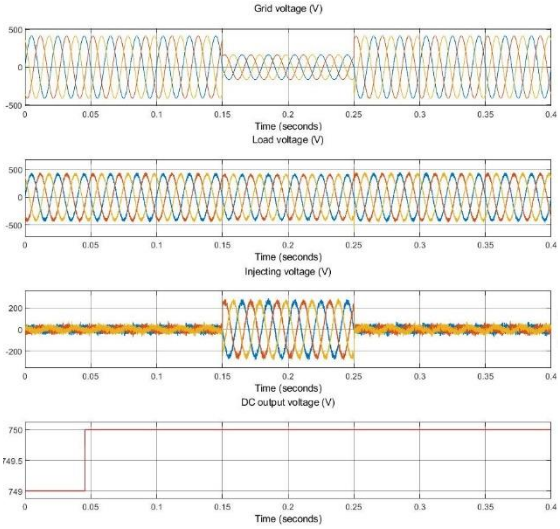


Fig 23: Performance characteristics with Fuzzy at 60% sag

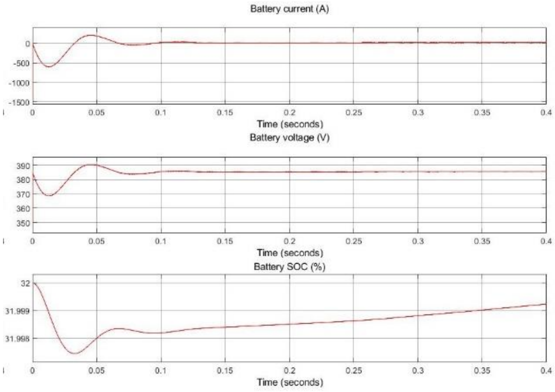


Fig 24: Battery characteristics with Fuzzy at 60% sag

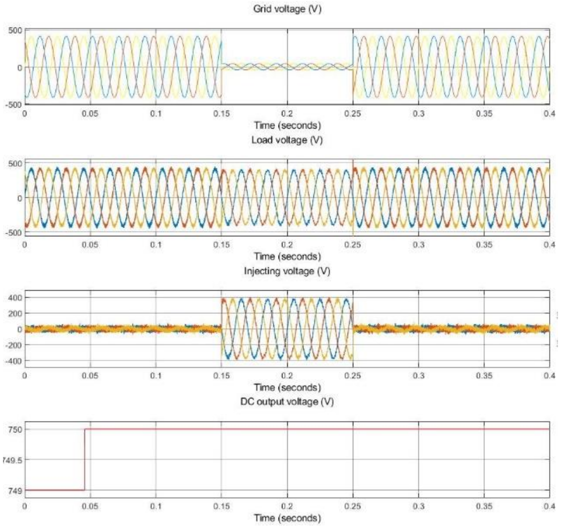


Fig 25: Performance characteristics with Fuzzy at 90% sag

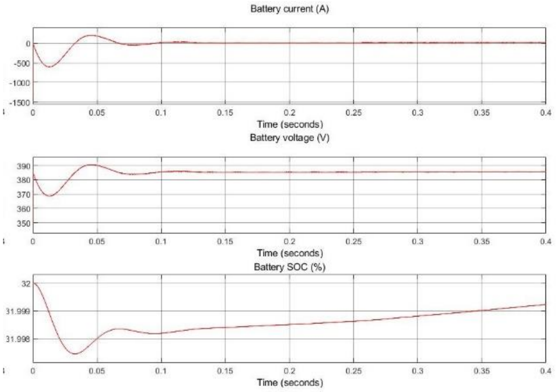


Fig 26: Performance & battery characteristics with Fuzzy at 90% sag

From fig 20-26 A fuzzy controller can minimise voltage and current ripples, achieve a quick transient response, and have minimal overshoot. to obtain constant DC output voltage. when obtaining a constant DC output voltage in a control system with nonlinearities, imprecise rules, variations, and the need for human interpretability, a Fuzzy Logic Controller (FLC) can offer advantages over a traditional Proportional-Integral (PI) Controller. FLC's adaptability and rule-based approach make it well-suited for such scenarios, where maintaining constant voltage in the face of changing and complex conditions is essential.

V.CONCLUSION:

This study examines The effectiveness of the charging station for electric vehicles (EVCS) equipped with Dynamic Voltage Restorer (DVR) and Under different voltage sag, fault ride-through capability (FRTC) under conditions, namely at levels of 30%, 60%, and 90% correspondingly. The sag in the grid voltage occurs at a time of 0.15 seconds. During this specific time frame, A voltage is applied to the load via the DVR-FRTC system. As a result, the across the load is kept at the specified standard value. Furthermore, the rectifier generated the predetermined direct current (DC) output voltage is ripple free . Throughout the duration of the voltage dip, the DVR-FRTC system starts to inject voltage in phase with the voltage of the load. . Consequently, The system is kept in a stable operating state by controlling the load voltage to its assigned value. Additionally, The output voltage of the rectifier is maintained at its nominal value. A fuzzy controller can achieve a constant DC output voltage by minimising voltage and current ripples, having a quick transient response, and minimum overshoot.

VI.REFERENCES

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