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ANFIS Controlled Bidirectional off Board EV Charger with Reactive Power Compensation and Reduced THD

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ABSTRACT

This article presents the usage of a utility integrated off-board Electric Vehicle (EV) battery charging system with compensation of reactive power and functioned in grid-to-vehicle (G2V) and vehicle-to-grid (V2G) operations. Its design includes a utility connected front end AC-DC cascaded H-bridge (CHB) converter that regulates power flow among the battery and grid via a back end bidirectional DC-DC operation. As a safety measure, the charger arrangement offers galvanic separation between the consumer end and the remainder. By managing EV power and battery current, the suggested approach follows the active power command for G2V and V2G operations, as well as the reactive power compensation from the utility system as available using ANFIS controller. A control algorithm designed around an adaptive notch filter is also created for network phase approximation and twisted standard current synchronization. The suggested control technique removes the need of phase locked loops (PLLs) in the design of controller. As a consequence, the controller's estimation difficulty decreases while its steady-state and transient functionality improves. The results are achieved using MATLAB atmosphere, and the efficacy of the suggested mechanism method is verified throughout the EV charger's V2G and G2V compensation of reactive power.

Keywords—Grid to vehicle, EV charger, Power quality, Vehicle to grid

1. INTRODUCTION

EV have freshly increased popularity in industrialized nations due to lower fuel consumption and greenhouse gas productions [1]. The rising fitting of off-board accusing positions is one of the primary reasons driving the increased penetration of EVs. The off-board mount control electrical network can be operated in either bidirectional or unidirectional operation [2-3]. The term bidirectional process refers to the transmission of active electricity in two directions, namely G2V and V2G. Because of the deposited energy in EV batteries, V2G action is exciting in the grid [3-4].

Even if the energy in batteries has the ability to meet the utility storage requirements, deterioration of the EV strings throughout V2Gprocess remains a worry [5-6]. Chargers, on the other hand, can provide good quality power additional services like as a voltage regulation, compensation of reactive power, compensation of harmonics and power factor adjustment deprived of requiring the usage of EV systems with utility[5].

Because they are additional flexible to power heights, off-board systems are preferable than on-board systems for providing these auxiliary services [6]. The energy source provides reactive current in a traditional power system. This creates extra losses in the lengthy broadcast and distribution system reactance, lowering system regulation. Additional voltage loss at line reactance decreases the system quality of voltage. As a result, generating reactive load demand locally is favoured. Furthermore, domestic loads such as compressors, refrigerators, washing machines, microwaves, and smart gadgets, among others, consume reactive electricity from the system for which users pay insufficiently. EV bidirectional charger, additionally, may deliver reactive power locally without the use of extra VAR suppliers. This paper emphases on the procedure of an EV charger in grid examination. As a result, the installation of off-board charging stations with surrounded utility auxiliary services in underused public spaces such as parking lots, restaurants, retail malls, residential complexes and office buildings stimulates the implementation of EVs.

The proposed EV charging system in [7] is intended to compensate the utility for reactive electricity. To accomplish continuous compensation of reactive power, the voltage of the DC link is adjusted by EV battery system, which have an impact on their life. Furthermore, it undergoes additional discharging and charging cycles, which reduces the life of the batteries. The charger's instantaneous functioning in V2G and G2V with compensation of reactive supply is not described further. Correspondingly, in [8-9], the design is employed to provide reactive power assistance to the grid. By means of EV batteries to adjust DC connection voltage, on the other hand, decreases their performance and longevity. Show the reactive power correction operation of an EV charger while also running G2V. The proposed charger control technique, on the other hand, manages the DC system by means of batteries, and controlled reactive power with V2G is not explored. However, it cannot investigate the charger's instantaneous functioning in further than one operating style at the same time.

2. MATERIALS AND METHODS

It describes the development of an efficient control method for a two directional off board EV charger in order to provide reactive power adjustment when recommended from the utility system. The suggested charger regulator additionally supports reactive power correction while the charger is operating in V2G or G2V mode. In this research the reactive power compensation is achieved at V2G operational mode. Furthermore, the suggested charger architecture includes galvanic separation, which increases the EV charger's reliability in real applications. During charging, the charger controller after compensation provides best power factor with unity. By removing PLL from the controller, the planned charger regulator method employs an adaptive notch filter (ANF) for synchronization with the grid. As a result, the regulator has enhanced variations and lowered complexity of implementation. In addition, direct control of power is used in the controller to achieve a quick transient reaction to a variation in command power. The usage of ANF in its place of PLL increases the charger's performance in long run steady operation. The DC connection output voltage regulator is introduced to the internal current controller loop to keep the DC connection voltage at its orientation value.

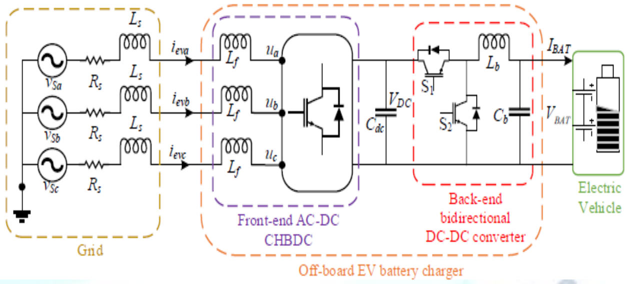

FIGURE.1: Suggested system configuration

Bidirectional Electric Vehicle Charger

Figure 1 characterizes the off-board EV indicting prototypical layout. The created EV designer is utilized to evaluate the charger's compensation capabilities of reactive power as healthy as the charger's V2G and G2Vworking operation. The grid connected front ended AC-DC- CHBDC is a model with a one motivated voltage source. Figure. 2 represents the complete structure design of the utility looking converter. The present converter configuration has three H-bridge components per phase.

The main side of a single-phase toroidal core transformer (TCT) is connected to every H-bridge output. The 3 transformers secondary winding elements are connected in series, and the secondary voltages of all transformers are summed together to generate the yield voltage. As seen in Fig. 2, every H-bridge donates similarly to the output phase voltage, i.e. 33.33%. TCT are used as a high frequency link in front-end converters, but their use at the yield end recovers presentation above outdated transformer-based designs. The TCT allows the system to run on a sole DC excitation voltage. Additionally, it removes the need for extra voltage equivalent sensors to ensure identical power delivery throughout the segments. The described H-bridge architecture also has very little charging current Harmon's, voltage and current control experiences and galvanic isolation. To enhance the converter output voltage quality, the network interconnected CHBDC is linked to utility system via L-filter, as illustrated in Fig. 1. Because of its multilayer construction, the L-filter is capable of eliminating switching harmonics of higher-order nature. The EV batteries are discharged and charged using the back-end DC-DC operation. Figure.1 depicts the BBDC's detailed circuit configuration. By varying the both switches (S1, S2), the described setup may function in two modes such as boost and buck operation. Manipulating switch S1 works the BBDC as a buck operation, while manipulating S2 activates boost mode. As a result, discharging and charging EV batteries may be talented by working the BBDC in boost and buck operation.

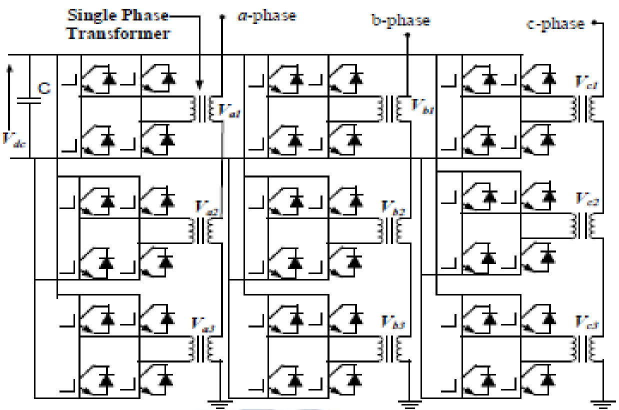

FIGURE.2: CHBDC internal structure

Control design of the suggested model

The control considered has two major goals: the first operation includes the EV battery charging in G2V operation and the second function includes the assignment of active power in V2G operation when grid requires it and also to supply sufficient reactive power when grid required for proper operations. Figure.3 presents the detailed structure of the controller. The suggested regulator method makes use of ANF to retain the grid and the pony in synchronization. The ANF functions successfully nevertheless of organization disorders and substitutes the ordinary PLL in the system controller.

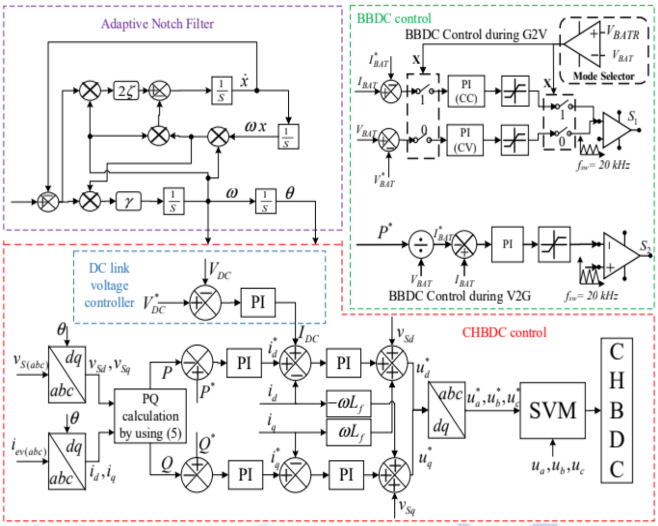

FIGURE 3: Detailed structure of the controller

Grid to Vehicle(G2V) Mode operation:

In G2V operation, the sufficient active power taken commencing the utility by the charger to control the batteries. For charging of the batteries, this study employs the constant voltage (CV) and constant current (CC) techniques. In the preliminary charging state, the charging current reference is fixed to the accurate power level below continuous current till the voltage of the battery reaches the manufacturer's rated permissible voltage level. Following that, the system is charged at highest voltage level by decreasing current checkout the current extents its esteemed threshold value and the voltage of battery extents its highest level. In this approach of operation, the CHBDC mechanism system follows the charging power instruction P and keeps UPF at its input. The reactive power value kept Q = 0 in this operating state. The BBDC acts as a buck operation during charging by managing the interchanging of S1 to manage the battery charging current (DEF) and voltage (GDEF). Figure.3 describes the BBDC control topology during G2V operation. The variables are identical to those in Fig 1.

Vehicle to grid(V2G) Mode of operation:

In this style of process, the EV charger maintains a 180 degrees phase shift among EV voltage and current by fixing the reactive power reference to zero value. The control method of the EV charger gets the command to create the reference current (reference power P and time interval). Without accounting for the loss of power in the EV charger, the current reference of the battery may be calculated. Energy storage to the electric grid. When an EV is associated to the utility, the charger's chief purpose is G2V working. Though, with the addition of a BBDC, power transmission in two ways is allowed for a limited time.

TABLE.1: Test system modelling parameters

Parameters	Specifications
Charger apparent power	12.6KVA
CHBDC Filter	L_f=2.5mH(25A)
BBDC elements	L_b=3.7mH,C_b=660μF
Grid Impedance (Z_s)	R_s=0.1Ω of a,L_s=1.6mH
DC link capacitor(C_{DC})	2200μF/500V
Transformer(CHBDC)	1kVA,1-ϕ,Toroidal core
Supply System	230Vrms,50Hz
EV Battery	Nominal voltage= 192V

3. SIMULATION RESULTS AND VALIDATION

The Simulink design is created to assess the suggested EV charger operation efficiency throughout the charger's described modes of operation. Table-I lists the test system parameters utilized in this work. The charger first operates in G2V mode, accusing the battery through the consideration which would give sufficient reactive power when it is required from the effectiveness system. Based on the recommendations of the reactive power, the charger changes its modes of operation.

If the utility requires reactive power, the designed controller can operate with various charging power. Figure.4represents the charger's presentation in G2V operation when charging with P=12 kW. Fig.5 depicts, the EV charger output voltage THD in G2V condition which is 1.26% with proposed controller. Fig.6 presents the yield current of EV charger in G2V condition whereas Fig. 7 represents the yield current THD of EV feeder in G2V condition is 6.95%. Fig. 8 represents the active power output of 12 kW in G2V operation. Fig.9 represents reactive power requirement of EV charger in G2V condition which is fixed at zero to operate the system at unity power factor and the Fig. 10 illustrates the DC link voltage variation. The utility recommends inductive reactive power from the charger during charging at 1.5 s by changing its operational mode from G2V to G2V with V4G.Q= 9.8 KVAR and P= 6.8 kW are the power commands sought from the grid.

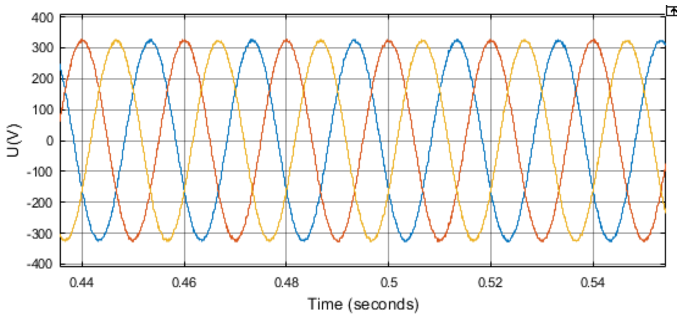

FIGURE.4: EV charger output voltage in G2V condition

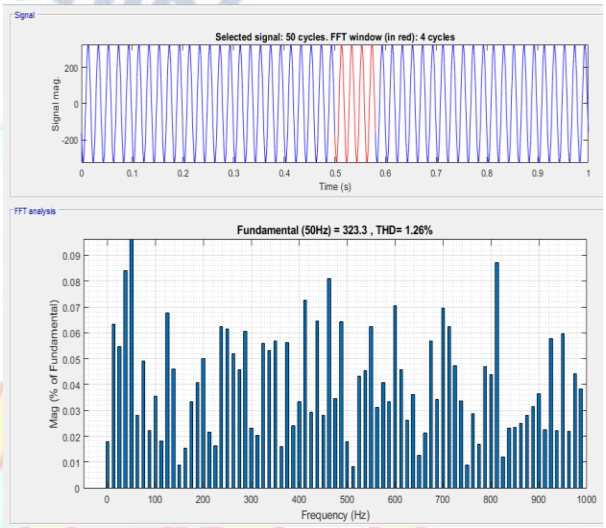

FIGURE.5: EV charger output voltage THD in G2V condition

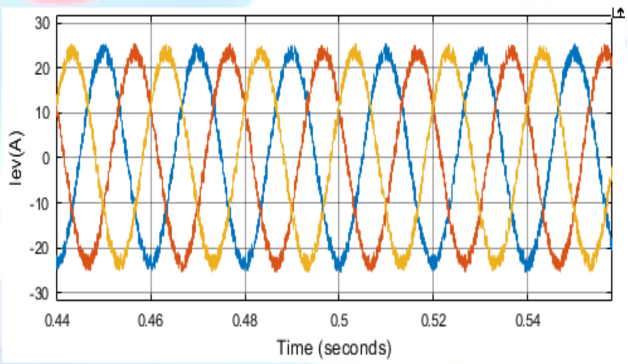

FIGURE.6: Output current of EV charger in G2V condition

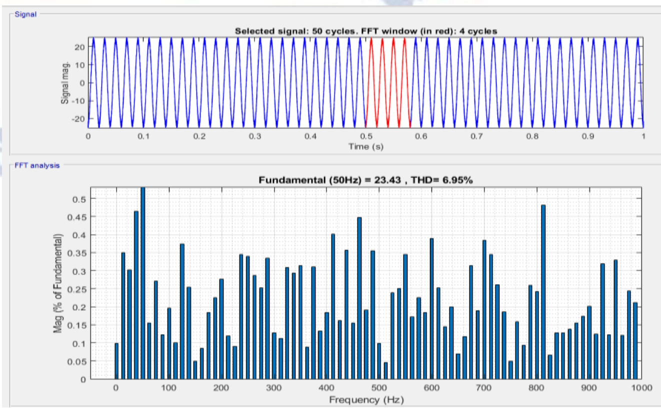

FIGURE.7: Output current THD of EV charger in G2V condition

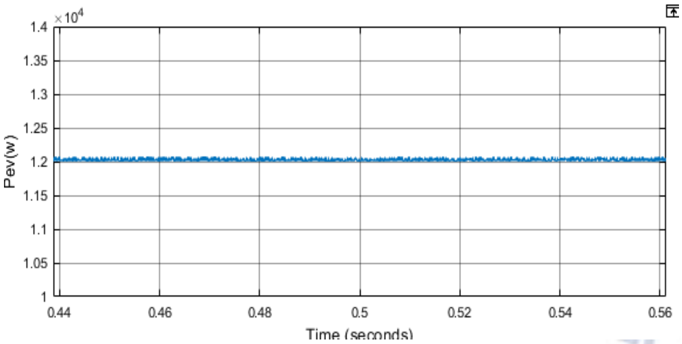

FIGURE.8: Active power output of EV charger in G2V condition

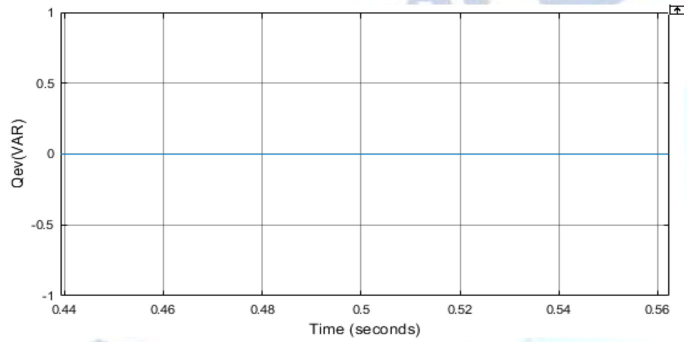

FIGURE.9: Reactive power output of EV charger in G2V condition

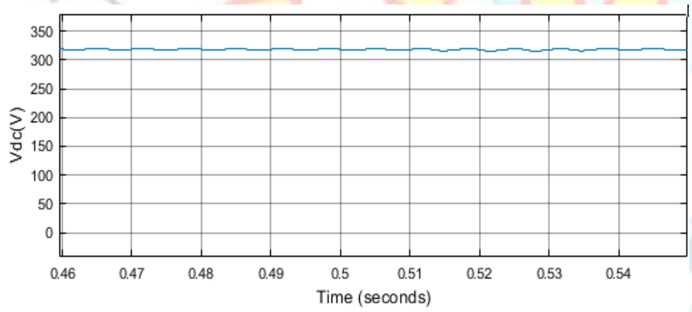

FIGURE.10: DC link output voltage of EV charger in G2V condition

4. CONCLUSION

This paper presents an effective controller method that considers into description G2V and V2G modes, as healthy as compensation of reactive power, and includes EVs as an active system that may supply and feed the energy with storage advancement. For safety reasons, the charger setup includes galvanic separation at the operator area. The devised control procedure performs adequately in various operational conditions, and the approaches of process are healthy implemented when the power instruction is sent. The design offers excellent steady and transient presentation. In lesser than two grid cycles, the off-board charger works to the power signal variation. The battery system is unaffected by reactive power value, which extends life of the battery. The results satisfactorily recommends the suggested controller operation throughout various power signal operations. The results demonstrate that the proposed charger is a good contender for reactive power support amenities to be used by the grid system.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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