A Novel Fuzzy based Fast DC Charging for Electric Vehicle Charging Station

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Abstract:
The smart grid might make use of electric cars (EVs) as distributed energy storage devices to perform a variety of regulatory duties. The current trend, however, is to jointly manage a fleet of EVs via a new stakeholder called an aggregator in order to have a substantial enough influence on the grid. Based on the availability, mobility patterns, and state of charge (SOC) of each EV battery, the aggregator assigns an active and/or reactive set-point to each EV within a time frame. The goal of this research is to standardize EV charger currents based on the individual user set-points that are sent to the aggregator. A variety of control strategies for bidirectional active power regulation are compared under ideal and distorted source conditions. Management of charging operations for individual EVs is decentralized, as opposed to the centralized control that manages the transformation of power from the AC grid to the DC bus. Switching from vehicle-to-grid mode can be done with little disturbance since the electric power exchange does not need the station and automobiles to be in continual touch with one another. Energy from EV batteries is discharged into the GSS by several Discharging Units (DUs), which are responsible for supplying the grid with both active and reactive power. Here, we provide a fuzzy-based control strategy for EVs that helps the grid while reducing their active and reactive power usage. Active and reactive power flow from the GSS to the grid are determined by the node voltage and available energy in the GSS. Simulations in Matlab and Simulink are used to show how the station operates. The results prove that the proposed model is workable, and the control system is capable of fast DC charging and vehicle-to-grid functioning.

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I. INTRODUCTION

The development of more user-friendly electric vehicles has as one of its key goals the reduction of the charging time for the battery. One interesting strategy in this approach is rapid DC charging. Ten to twenty minutes is all it takes to recharge [1]. All levels make use of external recharging infrastructure for electric vehicles (EVSE). With the intention of easing the way for their real implementation and future research on the topic, the authors of this work suggest and develop, from a pedagogical aspect, a model and simulation of a quick DC charging station for electric cars.

Commercial production of electric cars has begun in response to rising urban pollution concerns and significant advances in battery development (EV). They represent a new and rapidly expanding market. While parked, the cars' batteries might contribute to the power grid by performing several useful functions. When electric vehicles (EVs) only charge their batteries using a strategy compatible with Demand Side Management (DSM) programs, this is known as grid-to-vehicle, (G2V), mode; when EV batteries can also discharge to accomplish regulation services to the grid, this is known as vehicle-to-grid, (V2G), mode [1]. Some of the regulatory services that electric cars might provide to the grid include: demand side management, renewable energy resource (RES) smoothing, energy injection, and ancillary service supply [2]. Initially, the latter may be aided by a charge schedule that factors in both economic and grid concerns. Since this kind of load is "shiftable," charging may be adjusted to times of peak RES output, cutting down on pollution while also lowering charging costs due to more consistent RES injection. Ancillary service provision, in contrast to the aforementioned activities, requires bidirectional power flow, which presents both technical challenges and commercial potential for EV owners. To ensure the aforementioned services have a significant enough influence on the grid, aggregation is necessary to overcome the limited capacity, availability, and durability of individual batteries. A new kind of stakeholder known as an aggregator is increasingly being used to coordinate the management of a fleet or group of electric vehicles. The aggregator's primary goal is to maximize some objective function subject to limitations related to the availability of EVs, the user's movement patterns, the battery's state of charge (SOC), and the battery's degradation rate [3]. Algorithms for distributing EVs' active power set-points under aggregator management have been the subject of several published works [1, 3–5], with the ultimate goal of allowing EVs to take part in active power control reserve services. Many of them evaluate how well you define your goal function and how you handle limitations. Only a few sources [2, 6] discuss the potential for a group of EVs linked to a bus to help with reactive power support or even voltage regulation. Incentives for EV owners to take part in regulating services might include, for example, the provision of enticing services in exchange for participation, or the development of a charging/discharging pricing plan that varies in accordance with the battery state of charge. Two forms of control may be specified [7] depending on the incentive chosen: direct control, in which a service provider directly orders the charging/discharging rate of the EV batteries connected in a given time period, and indirect control, where the price is set by the person who owns the EV. Advantages of such direct control include prompt and predictable reactions to control inputs. Owners of electric vehicles (EVs) may be resistant to such a high degree of regulation because of the impact it may have on their vehicles' mobility. For that reason, it's best reserved for short-term remedies [13].

By sending pricing signals to EV owners, who may then choose to either pay more, reduce or reallocate their charging load, or just accept the higher cost, indirect control can be exercised. In the context of a Demand Side Management strategy, in which the EV owner is seen as a customer, this legislation makes sense; nevertheless, its applicability in the context of charging fees is now under investigation. One disadvantage is that you'll need to anticipate how owners will respond to different price signals. The gadget is suitable for long-term administration. Following an optimization approach to ascertain the contribution of each EV of an aggregate to offer a regulation service, each battery inside a time slot is assigned an active and/or reactive set-point.

II. BATTERY CELLS AND TRACTION DRIVES

Research papers detailing the design and implementation of various converter topologies and battery management systems. Complexity of circuit design, speed, voltage/current stress across devices, system efficiency, size, and cost have all been evaluated to determine the optimum BMS. Several traction drive topologies have been examined in terms of their blocking voltage, switching losses, and fault tolerance.

Series connections between battery cells are often used by battery management systems to supply the appropriate voltage for the DC link of a battery EV traction inverter [8]. After being charged and discharged multiple times, a rechargeable battery develops a voltage imbalance due to differences in cell leakage currents, temperatures, internal impedances, charge storage volumes, and chemical characteristics. Voltage inconsistency causes cell damage and shortens battery life [9]. This is why battery management systems (BMSs) are often included in battery packs these days [10]. The BMS relies heavily on the cells' state-of-charge (SOC) since it offers an accurate representation of the battery's state of health at any one moment. When the SOC is spread uniformly throughout all cells, cellular damage is mitigated [11]. Different approaches are used by passive and active BMSs to ensure charge parity. Passive BMSs use external passive resistors to drain the excess energy from cells with a higher SOC until their SOCs are equivalent to those of cells with a lower SOC. Alternatives to active BMS include resistors with a fixed value [12], [13] or a range of values [12]. Active BMSs allow cells with a lower SOC to receive the extra energy produced by cells with a higher SOC. Capacitors, inductors, transformers, and controlled switches or converters are only some of the active components used to buffer the energy transfer between cells in active BMSs topologies [12]. Since passive BMSs have fewer moving components, they are less complicated and cheaper to install. Slow equalization rates and low efficiency may be traced back to the inefficient dissipation of excess energy via the balancing resistors. Active BMSs are more complex and costly, but they give a faster balancing rate and higher efficiency. Here, we'll examine the various passive and active BMSs offered [12], explaining how they function, pointing out their advantages and disadvantages, and highlighting the key features that set them apart from one another.

Conversion-Based Battery Management The voltage of each battery cell or battery bank is balanced by power converters in converter-based BMSs. Some of these methods include the use of full-bridge converters (FB), buck-boost converters (BBC), flyback converters (FbC), quasi-resonant converters (QRC), and ramp converters (RC) (FBC). Although the balancing procedure is strictly regulated, the resulting BMS is complex and costly [14].

III. CUK CONVERTERS

The two-way CC balancing mechanism is seen here in schematic form. This method employs N 1 bi-directional Cuk converters, each of which consists of two switches, two inductors, and one capacitor, to maintain a constant voltage across N successive battery cells linked in series. Every converter is hardwired across two adjacent cells to allow power to flow from the higher-voltage to the lower-voltage one. Therefore, if you have a large number of cells, this method may take some time until the whole pack is in equilibrium. With the maximum voltage across each switch being equal to the maximum capacitive voltage (VB1 + VB2), low voltage MosFETs may be used as power devices to reduce conduction and switching losses [11].

Capacitors may be used to link cells in close proximity, with the direction of energy flow determined by the voltage differential between the cells and the switching function of the switches.

Power losses from switching the MosFETs may be reduced by designing the converter to operate in discontinuous capacitor voltage mode (DCVM). You can calculate the initial voltage of a capacitor by summing the voltages of its two adjacent cells [14]. This technology's ability to efficiently balance cells makes it helpful for electric vehicle (EV) and hybrid electric vehicle (HEV) applications; nevertheless, the balancing process is time-consuming and the control system is complex [13].

IV. BUCK/BOOST CONVERTER

Buck converters, boost converters, and combined buck-boost converters are typical active BMSs. A buck-boost converter may be used to transfer energy from a higher-voltage source to a lower-voltage source, or vice versa. The BBC methods are effective, suitable for modular building, and provide quick equalization times. However, achieving cell balance requires sophisticated regulation, which increases the complexity and expense of implementation [14]. Fig.1 is a schematic representation of the buck/boost conversion balancing system. With this method, N bidirectional SMs are utilized to equalize the voltage of N series-connected cells. Each SM consists of two switches, one inductor, and one capacitor. The converters may operate in either continuous conduction mode (CCM) or discontinuous conduction mode (DCM), depending on the control system and circuit parameters (DCM). Since the maximum voltage of each SM is equal to the cell voltage, low voltage MosFETs may also be used [14]. In the charging process, each SM acts as a buck converter. Therefore, capacitors from the output filters are connected in series to the dc source. When using this method of balancing, a filter capacitor at the SM input terminals is unnecessary [12]. Each SM's average input/output voltage is determined by both the voltage of its associated cell and the duty cycle of the SM, and during discharge, SMs drain current from cells to charge output capacitors, with the overall output voltage of SMs regulated to match the load voltage. Thus, the standard input/output voltage of the SMs may shift. If many SMs are connected in series such that they draw power from the same dc source and discharge to the same load, the combined input and output currents of all the SMs will be the same [14].

The battery current may be independently regulated in CCM by adjusting the duty cycles of the converters. As the number of times an associated SM is on duty increases, the current across that cell drops. By keeping all SMs on the same duty cycle, cell balance is achieved mechanically. This is because the switching time during which the inductor current goes from its maximum to its minimum value is shorter in the module with the higher voltage.

V. DESIGN OF CHARGING STATIONS

There are a lot of details to think about while laying up the circuit for the charging station. This technology has the following features:

The number of automobiles that can park there and the rates that may be charged are both affected by the amount of parking space that is made available.

Foreseeing the region's demand for quick charging stations.

the network's specifications, including its nominal voltage and maximum power permitted at the point of common connection (PCC).

The maximum amount of juice a single vehicle charger can produce. Fig. 1 depicts the proposed DC charging station configuration, in which an LCL filter and transformer link the inverter to the network and a DC bus distributes power to the various battery chargers. A charging station's rated capacity Srated in VAr is defined as follows, per (1):

$$S_{\text{rated}} = \frac{k_{\text{load}} N_{\text{slot}} P_{\text{EV}}}{\cos\phi}$$

where Nslot is the number of charging slots, PEV is the maximum power rate for a single EV, cos is the power factor, and kload is an overload factor for covering overloading during transients. Commonly, the DC connection voltage is changed to conform to the grid voltage. Thanks to the transformer connection to the grid, the DC bus voltage selection is made independently of the grid voltage level. However, the DC bus voltage is constrained below V min bat and above mmin, the minimum modulation index of the battery charger, according to (2).

$$v_{\text{dc}} \leq \frac{V_{\text{bat}}^{\text{min}}}{m_{\text{min}}}$$

and the nominal voltage on the DC bus is represented by vdc.

A. Determining the Capacitance of the DC Bus

The steadiness of the DC bus is proportional to the size of the DC capacitors used. Primarily, it has to be DC current ripple-proof. Since a DC bus may act as an interface for several EV chargers, it may need a sizable capacitance to handle the huge ripple current it encounters. Capacitance on a DC bus may be characterized by taking into account not only the voltage but also the resistance and inductance of the cables, as shown in [2]. As an added bonus, a feasible strategy is outlined ([3]). Here, we have a look at both methods; the DC capacitance is determined by the rate of change in transient energy and the capacitor's rated active power. In (3), we see an illustration of the proposed computation:

$$C_{dc} = \frac{S_{rated}}{V_{dc}^2} \frac{2nT\Delta r \cos\phi}{\Delta x}$$

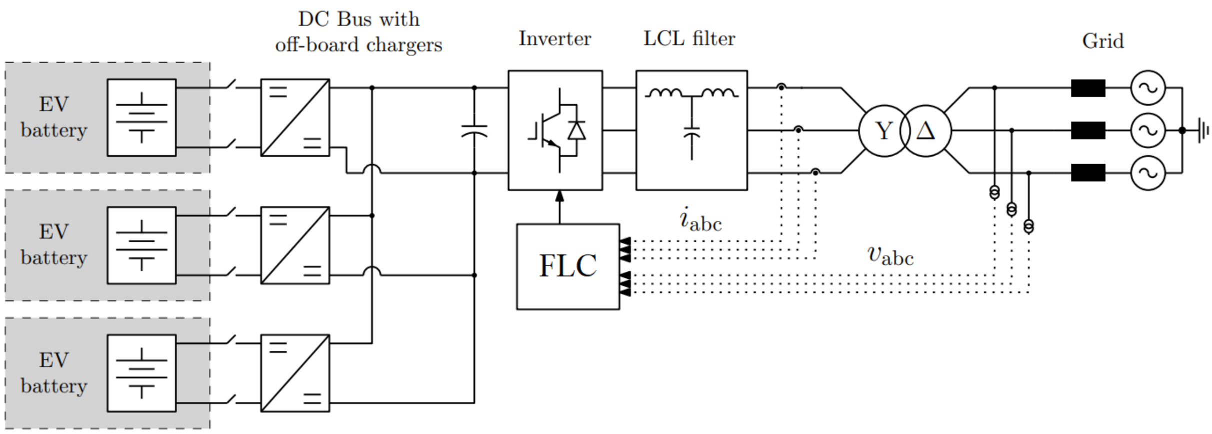


Fig. 1. Fast direct current charging station for electric vehicles.

A. EV battery

The current state of the art [4] consists of run time based models coupled with Thevenin's equivalent based models. Such an approach is used in this paper. The schematic of the battery model's electrical circuit is shown in Fig. 2. Here, Voc represents an open-circuit voltage that varies with the state-of-charge (SOC), and Rseries represents a series resistance that models the voltage-current characteristic. The quick action of the battery is mimicked by the RC parallel circuit.

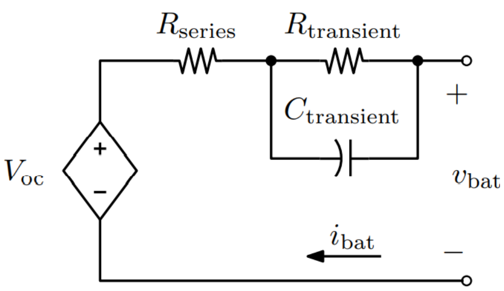


Fig. 2. Thevenin battery model.

Charger for Batteries

FIGURE 3: Battery charger schematic. This circuit employs two IGBT switches that are always controlled by a pair of symmetrical control signals, making it a bidirectional DC-DC converter [5]. Therefore, power may constantly flow in both ways. The left-side voltage vbat is raised when current ibat in the inductor Lbat is routed to the capacitor C during operation of the lower switch. When the upper half of the converter is switched on, it becomes a buck-type converter, with current in the opposite direction (ibat) flowing from capacitor C to the inductor.

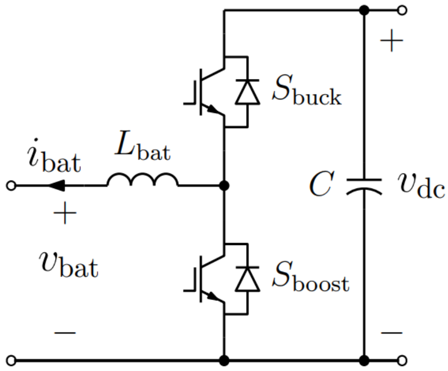


Fig. 3. Layout of battery charger.

B. Inverter with three phases

Because of its instructional value and ease of modeling, the inverter arrangement shown in Fig. 4 was selected for this investigation. An LCL filter is linked to the inverter in this case.

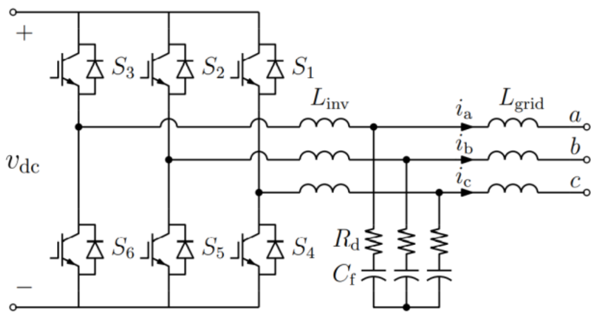


Fig. 4. LCL filter and three-phase inverter.

Least-Chiral Low-Pass Filter

Passive LCL filters are presently state-of-the-art for harmonic reduction of grid-interfaced distributed power sources [6]. Different methods for determining the filter parameters are presented in the literature, with examples being [7]–[9]. On the inverter side, the inductance choice is affected by a number of variables, including DC voltage, inverter modulation index, switching frequency, and current total harmonic distortion.

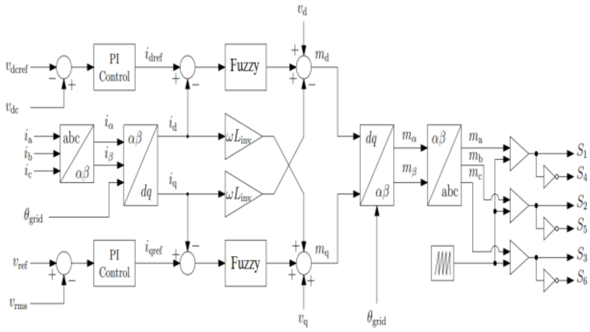


Fig. 5. Manage power for a charging station.

THD. However, the selection of capacitance and grid-side inductance is affected by reactive power, resonance frequency, and the ripple attenuation factor (RAF) [7]. The inverter-side inductance Linv, the filter capacitance Cf, and the grid-side inductance Lgrid of the LCL filter configuration shown in Fig. 4 are determined by using formulae (4), (5), and (6), respectively (6).

$$L_{\rm inv} = \frac{V_{\rm grid}^2}{S_{\rm rated} \cdot THD \cdot 2\pi f_{\rm sw}} \sqrt{\frac{\pi^2}{18}\left(\frac{3}{2} - \frac{4\sqrt{3}}{\pi} m_{\rm a} + \frac{9}{8} m_{\rm a}^2\right)}$$

$$C_{\rm f} \leq \frac{0.05 S_{\rm rated}}{2\pi \cdot f_{\rm grid} \cdot V_{\rm grid}^2}$$

$$L_{\rm grid} = \frac{RAF + 1}{RAF \cdot C_{\rm f} \cdot 2\pi f_{\rm sw}^2}$$

Inverter switching frequency (fsw), grid voltage fundamental frequency (fgrid), and modulation index (ma) are the unknowns to be solved for. THD often falls between 5% and 30% [8], whereas RAF typically falls between 20% and 25% [7]. The resonance frequency, as indicated in (7), should be between half and ten times the grid frequency; once you have the filter settings, you can verify this.

$$\omega_{\rm res} = \sqrt{\frac{L_{\rm inv} + L_{\rm grid}}{L_{\rm grid} L_{\rm inv} C_{\rm f}}}$$

You can give yourself some wiggle space if the final parameters don't quite meet the bill by determining a range for Cf, T HD, and RAF. Finally, as shown in Fig. 4, a damping resistor Rd is added, the value of which is given by the following expression:

$$R_{\rm d} = \frac{1}{3 C_{\rm f} \omega_{\rm res}}$$

VI. REACTIVE POWER MANAGEMENT IN SMART GRIDS

The distribution systems can't expand with the existing method of management. Different viewpoints need to be taken into account in order to include many decentralized energy sources. Smart grids include a vast landscape of possible adjustments to existing electrical systems of any and all voltage levels. Distribution network operation, energy management, resource management, and reactive power management are four primary study topics for smart grids. Controlling Energy Resources in a Smart Grid These researchers developed ERMaS, a simulation platform for overseeing decentralized power plants. For the purposes of ERMaS, it is considered that a VPP may manage many DERs in a certain geographical area of the network [7]. The VPP's ability to efficiently manage energy resources depends on its ability to uphold the agreements it has made with the many geographically scattered choices. The ERMaS program utilizes historical data in addition to daily forecast data to better manage energy resources. Details like this help pinpoint which DER may be accessible through the network. Predictions of consumption and output based on natural resources are stored in the database on an hourly basis (wind and sun). Information on network configuration, demand response possibilities, and storage capacities is also valuable. The ERMaS uses both deterministic and heuristic methods [7, 8] to solve the problem of energy resource management. Users that need precision in their findings may choose for deterministic approaches, while those who need speed can employ heuristics like Particle Swarm Optimization, Simulated Annealing, or the Genetic Algorithm [8]. The heuristic approaches were created in Matrix Laboratory (MATLAB) [9] whereas the deterministic approach, mixed-integer non-linear programming, was modeled in General Algebraic Modeling System (GAMS) [10] (MINLP). To interact with GAMS, MATLAB has also been used. GAMS is used to simulate the deterministic strategy, whereas MATLAB is responsible for data management, data acquisition, and result visualization. Fundamental to the ERMaS offering are algorithms for managing energy resources. When deciding how to distribute energy resources, time intervals are taken into account, within reason (T). Typically, 24 hour period of time is allocated for managing energy resources [8]. Both deterministic and metaheuristic strategies for managing energy resources may be implemented inside the ERMaS framework. [8]. Methods for Regulating Reactive Energy B. When it comes to energy resource scheduling, some methods prioritize medium and low-voltage power over high-voltage active power management. However, reactive power management must be considered to maximize the amount of their resources connected to the distribution network while minimizing losses and operational expenses. The objective function is a symbolic representation of the mathematical significance of the VPP's aims. A mathematical description (objective function) of the objectives is required so that the VPP can maximize earnings while reducing expenses.

Developing an objective function that allows for maximum profit is a well-liked strategy for optimal resource allocation.

Maximize f= $\forall t \in \{1,..,T\}$

Instead, a goal function is introduced that uses the amount of bus voltage deviations as a metric to test the efficacy and significance of reactive power control. For the purpose of avoiding unneeded blackouts, the target function should take into consideration demand response factors. If demand response is ignored, optimization reduces demand power to reduce power flow in the lines and, in turn, reduce voltage drop. We penalize the demand response variables by a factor (L) when we include them into the objective function in order to deter their use and the subsequent increase in the objective function.

A. Inverter control

In the dq-frame, it is proposed that cascade control be made available. This system consists of an outer voltage loop and an inner current loop [10, 11]. To match the voltage from the grid, a phase locked loop (PLL) is utilized [12]. As shown in Fig. 5, the recommended method of control. The outer d-axis loop controls the DC bus voltage, while the inner d-axis loop controls the active AC current. Thanks to the inverter's ability to boost voltage in either the positive or negative direction of the DC bus's current, the inverter may be used in either positive or negative current directions. The q-axis outer current loop regulates the AC voltage by adjusting the reactive current, which is controlled by the q-axis inner current loop. As a result of including dq decoupling-terms Linv and feed-forward voltage signals, the performance is improved during transients.

Input to the PLL block illustrated in Fig. 6 is the three-phase voltage detected at PCC. The dq-frame inverter takes the vd, grid, and output signals as its inputs.

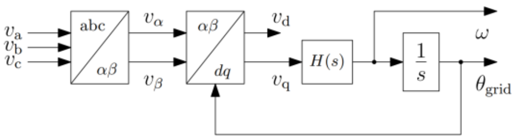


Fig. 6. An architectural representation of a power-line-coupled charger.

Controller Administration for Power Sources

Either constant current or constant voltage control approaches may be used, depending on the charging strategy used.

B. Proposed Diagram

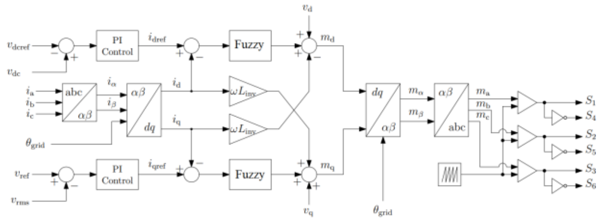


Fig 7. Charging Station Attempt at Designing a Control Panel

the battery charger's control panel. You may either (a) use a constant current technique or (b) use a constant voltage method.

The first part of the constant current method is to use the battery as a current source (also known as a unified control strategy). When the duty ratio at the output is more than 50%, the converter switches to boost mode. Observe Fig. 7 to see an example of this strategy in action (a).

A battery is still used in the constant voltage method, just as in the constant current method. When the output duty ratio mcv is high, the converter operates in buck mode. The procedure is shown in Fig. 7. (b).

FUZZY CONTROLLER

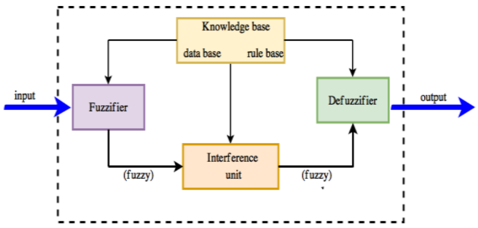


Fig8. Fuzzy controlling block

Fig.8 depicts the fuzzy controlling block, which includes the fuzzifier and defuzzifier. In contrast to conventional controllers, fuzzy controllers are rule-based. The Mamdani block is responsible for compiling inputs and outputs and executing the decision-making unit based on data and rules. a defuzzifier receives the FIS's fuzzified inputs and disperses the fuzzy results to produce the FIS's outputs. The outputs from each rule are then aggregated and defuzzified.

A. Fuzzification:

Fuzzification is a process that changes one set of values into another. In this case, we use membership functions that account for different languages. The Initiating Outcomes Of The block includes analog-to-digital converters for converting measured variables.

• Measurement errors, including those in the integral and derivation of state, must be controlled.

Allows for variation in the input and output variables' membership functions, including in terms of size, form, and distribution.

Decision making includes inference operations on rules, which is presented in section B. Inference. Connective operators like, & are used to sum up the values inside the rule.

Intersection: $\mathrm{AND}(\mu_a, \mu_b) = \min\{\mu_a, \mu_b\}$ (23)

Union: $\mathrm{OR}(\mu_a, \mu_b) = \max\{\mu_a, \mu_b\}$ (24)

Complement: $\mathrm{NOT}(\mu_a) = 1 - \mu_a$ (25)

where the values of membership are merged by directions. The aforementioned procedures are used to determine the rule firing strengths.

The outputs of rules are combined to provide a clear output value in step C, defuzzification. Center of the area (COA) [44] is the most often used defuzzification method.

$$Z = \frac{\sum_{i=0}^{n} \mu_i z_i}{\sum_{i=0}^{n} \mu_i} \quad (26)$$

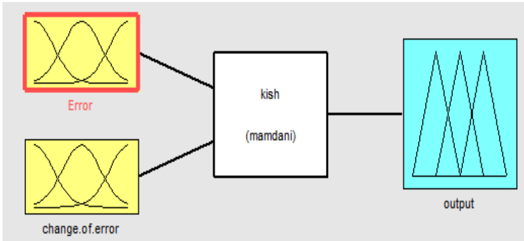
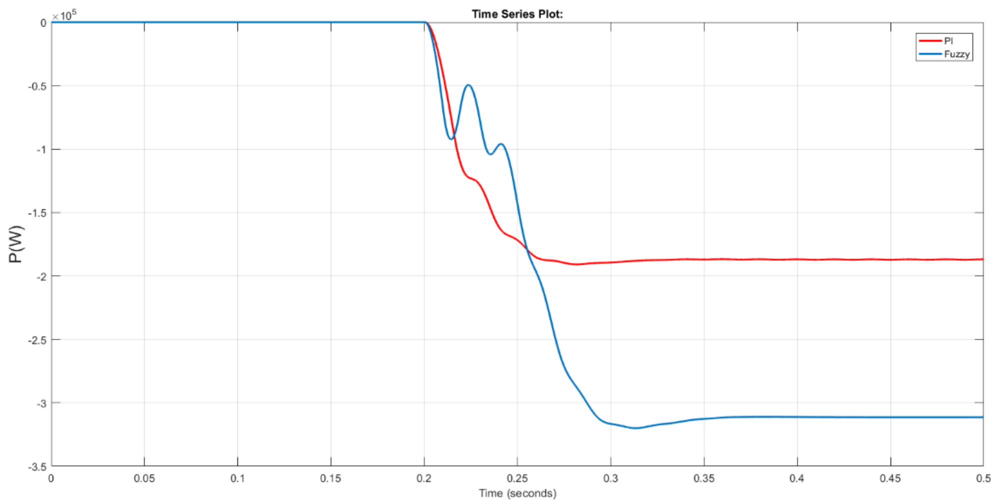
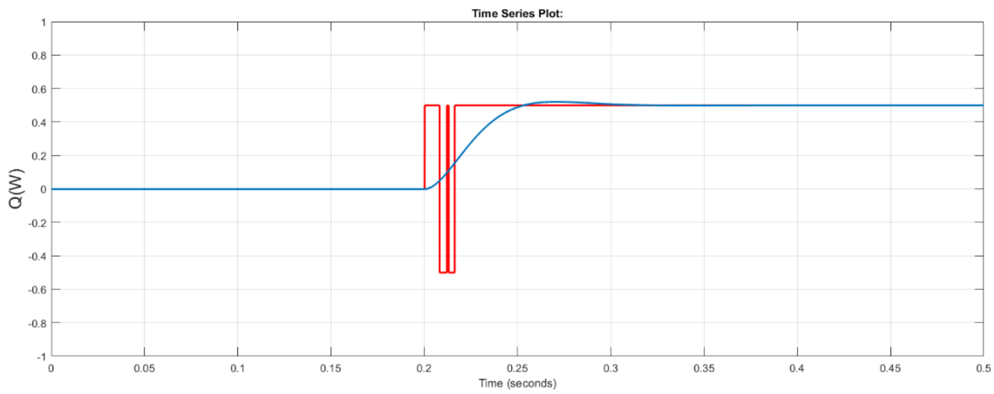


Fig9. displays the Mamadani block's error, change in error, and defuzzification output using two inputs.

It is up to the developer to determine the parameters of the fuzzy objectives and restrictions. Consequently, via the use of measurements, a tuning strategy for fuzzy control can be produced, one that will bring the system closer to the constraints and will ultimately compel the system to a superior performance according to the developer's aims and restrictions. Therefore, the fuzzy logic controller may be used to correctly determine weighting factors, the control goals, and avoid utilizing static values by taking advantage of the interdependence between various system variables.

SIMULATION RESULTS





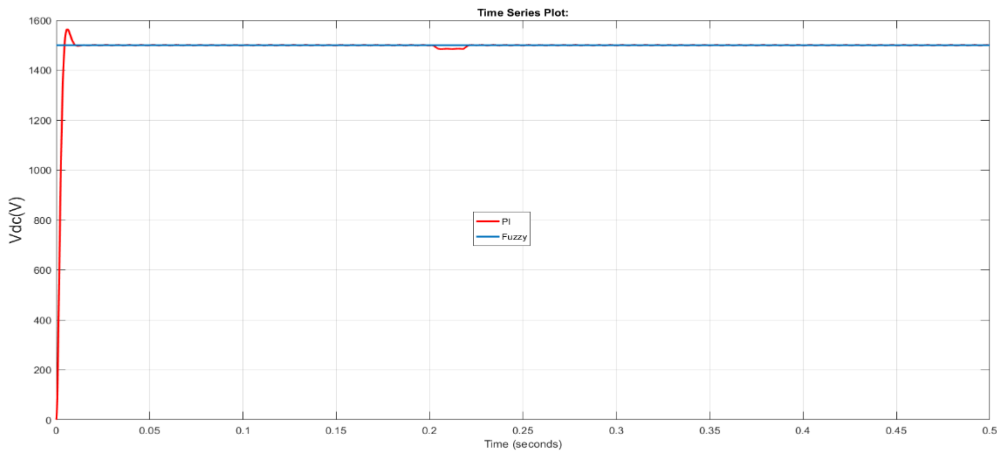


Fig.10 . Changes in (a) active and reactive power, and (b) DC bus voltage at a charging station for two electric vehicles

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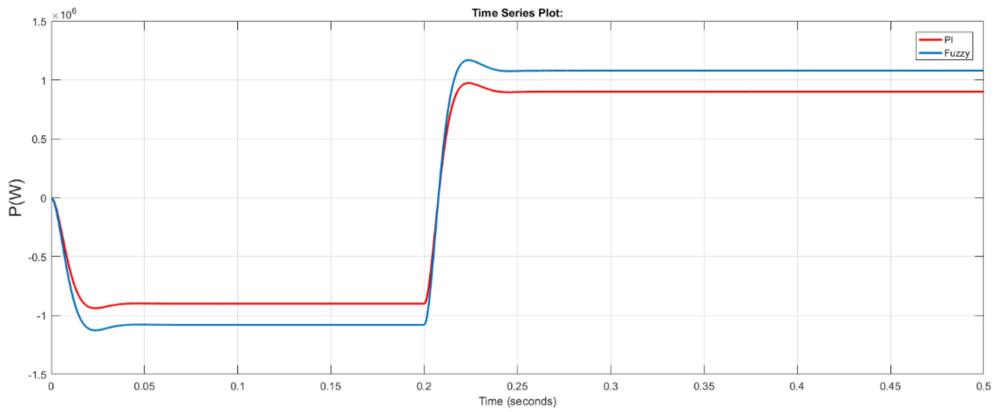

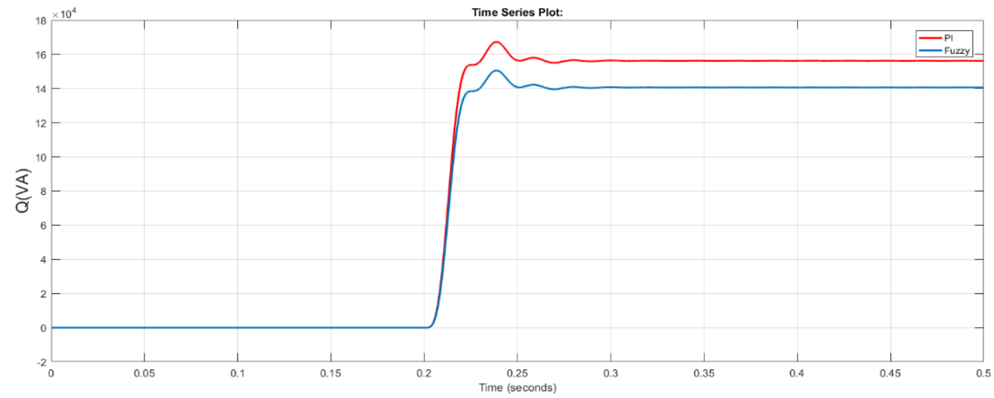

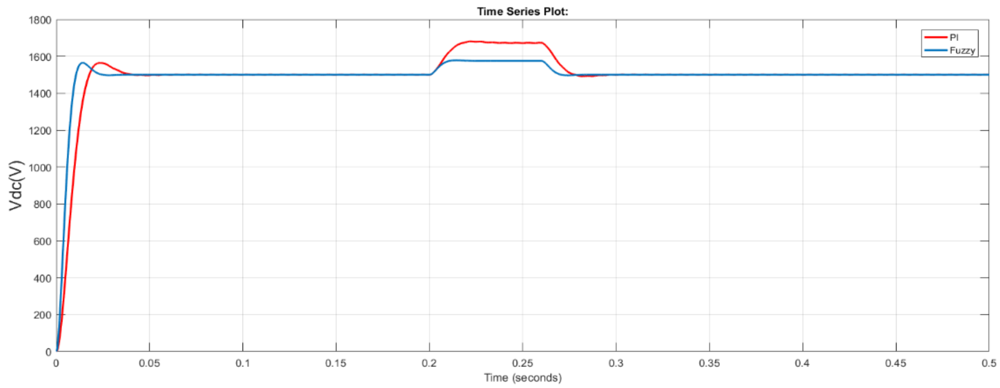

Fig. 11. Active power, reactive power, and direct current (DC) bus voltage are all measured at a charging station as part of a V2G and reactive power adjustment system.

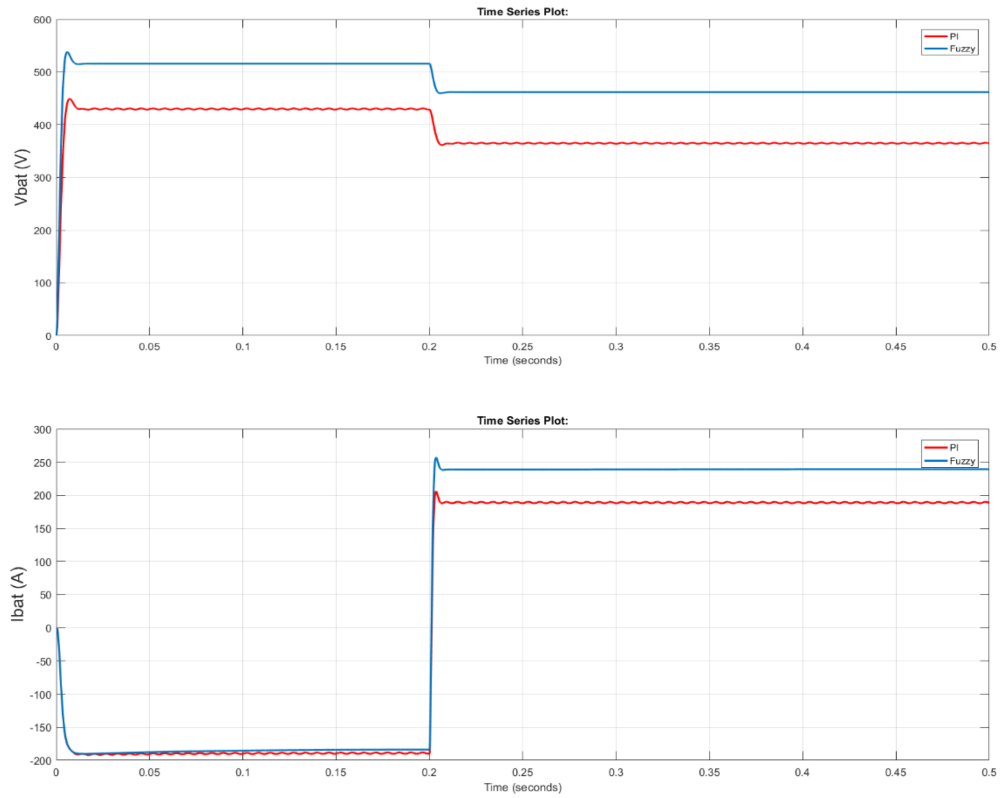

Fig. 12. Individual EV battery results for charging and discharging: (a) battery voltage, (b) battery current.

CONCLUSION

Combining FLC designs in a creative way that proves voltage and current control and convenience to the equilibrium of an EV system is a powerful strategy for taking use of model-based analysis. V2G and reactive power correction were also included in the charging station concept. Multiple EVs may be charged at once using DC fast charging, it was discovered. The simulation results effectively replicated the dynamic behavior of the DC bus voltage, battery voltage, and battery current. The results also show that a controlled transition to V2G and reactive power adjustment is possible. It's proof that this form of the controller can maintain a constant state operation. The simulation results confirm the great performance and quick response of the system.

REFERENCES

[1] http://www.sae.org/smartgrid/chargingspeeds.pdf

[2] Karlsson, P. Svensson, J. , ”DC bus voltage control for a distributed power system,” Power Electronics, IEEE Transactions on , vol.18, no.6, pp. 1405- 1412, Nov. 2003.

eISSN 1303-5150

[3] Mishra, M.K. Karthikeyan, K. , "A Fast-Acting DC-Link Voltage Controller for Three-Phase DSTATCOM to Compensate AC and DC Loads," Power Delivery, IEEE Transactions on , vol.24, no.4, pp.2291-2299, Oct. 2009.

[4] Min Chen and Rincon-Mora, G.A., "Accurate electrical battery model capable of predicting runtime and I-V performance" IEEE Transactions on Energy Conversion, VOL. 21, NO. 2, June 2006.

[5] Mohan, N. "First Course on Power Electronics Converters and Drives" Minneapolis, USA. ISBN 0-9715292-2-1.

[6] Dannehl, J. Fuchs, F.W. Thgersen, P.B. , "PI State Space Current Control of Grid-Connected PWM Converters With LCL Filters," Power Electronics, IEEE Transactions on , vol.25, no.9, pp.2320-2330, Sept. 2010.

[7] Min-Young Park, Min-Hun Chi, Jong-Hyoung Park, Heung-Geun Kim, Tae-Won Chun, Em-Cheol Nho, "LCL-filter design for grid-connected PCS using total harmonic distortion and ripple attenuation factor," Power Electronics Conference (IPEC), 2010 International , vol., no., pp.1688-1694, 21-24 June 2010.

[8] Araujo, S.V. Engler, A. Sahan, B. Antunes, F., "LCL filter design for gridconnected NPC inverters in offshore wind turbines," Power Electronics, 2007. ICPE '07. 7th Internatonal Conference on , vol., no., pp.1133-1138, 22-26 Oct. 2007.

[9] M. Tavakolini Bina, E. Pashajavid "An efficient procedure to design passive LCL-filters for active power filters"'. Electric System Power Research. 2009.

[10] Yazdani, A. Iravani, R. "Voltage-Sourced Converters in Power Systems - Modeling, Control and Applications" John Wiley and Sons, 2009 - Technology and Engineering.

[11] Blaabjerg, F. Teodorescu, R. Liserre, M. Timbus, A.V., "Overview of Control and Grid Synchronization for Distributed Power Generation Systems," Industrial Electronics, IEEE Transactions on , vol.53, no.5, pp.1398-1409, Oct. 2006.

[12] Se-Kyo Chung, "A phase tracking system for three phase utility interface inverters ," Power Electronics, IEEE Transactions on , vol.15, no.3, pp.431-438, May 2000.

[13] MATLAB Simulink SimPowerSystems 7.6 (R2008a) "SimPowerSystems Library Documentation" 2008.

[14] Mohan, N. Undeland, T. Robbins, W. "Power Electronics Converters, Applications, and Design" ISBN 0-471-22693-9.

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