FREQUENCY CONTROL OF AN EV POWER SYSTEM WITH THE GENETIC ALGORITHM

Miss MD SAMEENA[1], Mrs. T. RAJESWARI[2]

[1]*PG scholar in the Dept. of Electrical & Electronics Engineering, Holy Mary Institute of Technology & Science, Bogaram(V), Medchal District, Hyderabad, India.*

[2]*Assistant Professor in the Dept. of Electrical & Electronics Engineering, Holy Mary Institute of Technology & Science, Bogaram(V), Medchal District, Hyderabad, India*

Abstract— This research proposes a power system frequency control architecture which leverages Open Charge Point Protocol a rising open-source protocol for charge rate control of electric vehicles. Unlike conventional research that focused on building a high-performance controller, this research puts emphasis on the ease of deployment. Specially, this research explores the design of a frequency control architecture around the basic functionality of an open-source protocol while allowing substantial performance without the need for a well-tuned specialized protocol. As the usage of open-source protocols cannot provide a quick response, the proposed architecture alleviates this limitation by (a) utilizing a hierarchical structure to emulate a faster control interval and (b) providing a model predictive controller with system integrity protection scheme behaviour to have sufficient performance under both large and small disturbances. The overall architecture is evaluated against an aggregated power system frequency response model on Simulink for both large and small disturbances. Compared to a tuned proportional integral derivative controller on the same architecture, the proposed architecture observed an average reduction of 21.77% in nadir in the step disturbance test and an average reduction of 36.27% in standard deviation from the nominal frequency in the load variation test.

Keywords— Electric vehicles, frequency control, open-source protocol, architecture alleviates.

1. INTRODUCTION

A. BACKGROUND

With accelerating decarbonisation, massive quantities of electric vehicles (EVs) and renewable energy sources (RES) are expected to enter the power system in the coming years. However, replacement of traditional generation with RES, combined with variation originating from both RES and EVs, has brought about concerns in maintaining power system frequency one metric that is difficult to control through investing in traditional power system network components. Concern over power system frequency have been gaining focus with the prevalence of frequency related blackouts such as the Hokkaido blackout of 2018 in Japan. As a response to this rising concern over power system frequency, utilization of EVs in load frequency control (LFC) have also been gaining attention.

B. LITERATURE REVIEW

EVs in LFCs have been researched for approximately two decades, where majority of the significant research started to emerge in the last 10 years. Early research focused to resolve fundamental issues such as state-of-charge (SoC) management or performance of LFC without considering timeframes such as primary or secondary frequency control. For instance, is one of the significant early works which addressed LFC while maintaining SoC. Other key research from this era have also laid the foundation of EVs with LFC. These include hierarchical model predictive controller (MPC), fuzzy controller, robust proportional integral controller by using a H2/H1control approach, and use of distributed functional observers have laid the foundation for the modern EV based LFC, where variants have been proposed based off of these work. As the value of utilizing EVs in LFC became apparent, research started to expand into specific issues. For instance, designing specific controllers for different timeframes, primary (short-term) and secondary (medium-term), became popular. Primary control included frequency droop controllers [6], mixed hierarchical control between traditional generation and EVs, Imperialist Competitive Algorithm (ICA) tuned MPC, user selectable vehicle-to-grid (V2G) schemes, and controllers mixed with high-voltage direct current (HVDC) lines. Generally, research in this timeframe focused on building a high performing controller and control architecture to maximize the system's resistance against large disturbances. On the other hand, for secondary control, proposed variations of fuzzy control. Research in this timeframe focused mainly on combatting smaller disturbances, hence applying a less rigorous controller.

Other research continued to focus on specific issues such as SoC maintenance performance of LFC, battery degradation cost or even time delay was especially significant since the actual control time delay of EVs in frequency control was field tested. Despite alternative architectures existing, research have continued to develop around a hierarchical architecture.

Although an explicit reason has not been stated, the simple to implement structure of hierarchical architectures, as opposed to distributed architectures that require measures to preventing hunting oscillations, may have led to an interest in pursuing hierarchical architectures. Research such utilized a hierarchical architecture due to the intuitive implementation. On the other hand, research relating to controller shave yet to reach a single consensus. According to the recent work of most controllers fall under an integral order, fractional order, intelligent, or cascaded structure. Of which, fractional order and intelligent controllers have been popular. Fractional order controllers have been gaining attention with the added ability to better tune than traditional integral order controllers due to the fractional order terms. One drawback is in determining the optimal parameters for such controller, and research such as and have proposed variants of fractional order controllers using different tuning methods. Unlike proportional integral derivative (PID) controllers, which is simple to tune, the current state of tuning fractional order controllers relies on metaheuristic methods. All three subsets of intelligent controllers (fuzzy, neural, and others according to are still researched. For instance, and proposed variants of fuzzy proportional integral (PI) controllers. Furthermore, recent advancements in artificial intelligence led to the introduction of reinforcement learning based controllers and long-short term memory (LSTM) and deep neural network (DNN) based controllers. Despite the long history of MPC in EV-inclusive LFC, MPC still continues to be well researched as seen in and other types of controllers, such as static output feedback controller based on refined-Jensen inequality and event-triggered controllers have also proposed in the recent years.

C RESEARCH GAP AND CONTRIBUTIONS

The past decade has shown that various controllers are effective in stabilizing the power system frequency with EV charge rate control. Adaptive, droop, MPC, fuzzy, PID controllers have all observed a sufficient performance. Even elementary control schemes such as outlined in was adequate to show that benefits exist. As LFC utilizing EVs became widely known, real-life application has been gaining traction. The Parker Project in the Danish grid explored the viability of ancillary services, protocols, and scalability through a field test. The study concluded that ancillary services currently considered in the Danish grid is possible using EVs, V2G capabilities works well for certain subset of EVs, and scalability in functions in accordance with Market Model 2.0 was feasible. However, the study also found that Open Charge Point Protocol (OCPP) with certain chargers exhibited delays of several seconds to respond to control signals. Similarly, as part of the Kansai Virtual Power Plant (VPP) Project in west Japan (Kansai), LFC using EVs, and battery resources were also verified to be effective for both governor free equivalent and LFC regardless of the communication channel utilized (dedicated or encrypted IP). According to the use of a single vendor (closed protocol) mixed in with other battery resources have shown to be adequate to follow LFC control signals.

Overall, through these field studies, the viability of LFC is indisputable; however, to achieve a cost-scalable and deployable solution remains a challenge. The use of commercial internet, which is far more economical than dedicated lines, is viable as reported. Such use of commercial internet would require a certain level of standardized protocols. One rising standardized protocol is OCPP, which is a front-end (charger to aggregator) protocol that is compatible across different charging stations with varying chargers (CHAdeMo, ISO 61851 PWM, etc.). The challenge is the inherent delay of introducing such front-end protocol would have which can lead to reduced performance of the overall LFC.

Given the above discussion, the motive of this research is to design a practical frequency control architecture based on OCPP to offer sufficient performance. Hence, the specific contributions of this research are:

1) A frequency control architecture characterized by an asynchronous hierarchical structure. This allows a more granular control signal even while using OCPP.

2) A model predictive controller to acts as the central controller within the architecture. The model predictive controller incorporates a system integrity protection scheme (SIPS) behaviour to allow better protection against both small and large disturbances.

2. PROBLEM FORMULATION

A. POWER SYSTEM MODELING AND FREQUENCY CONTROL

Power system frequency refers to the fundamental frequency of the sinusoidal voltage waveform. In transient-states, power system frequency differs throughout the system; however, since this research is on LFC, which has time ranges several orders higher than transient, frequency is assumed to be the consistent throughout the system like most studies. With such assumption, Fig. 1 models the power system for this research. The general model is based on where the power system frequency deviation (in per-unit) occurs as result of the total power mismatch (i.e., difference between generated and consumed power). The model considers all relative support from EVs (reduction or increase in charging rate) as an extra electrical power injected into the system. For more details on the model, refer.

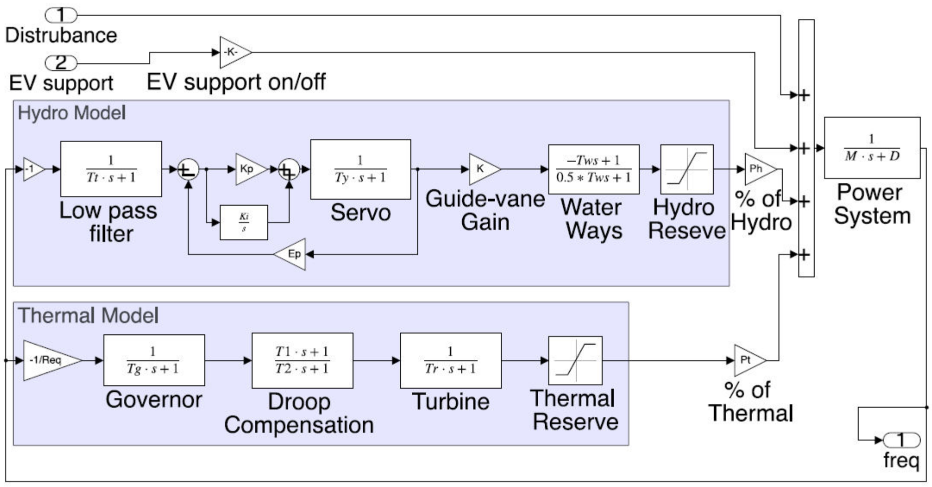


FIGURE 1. Power system model assumed in this research based.

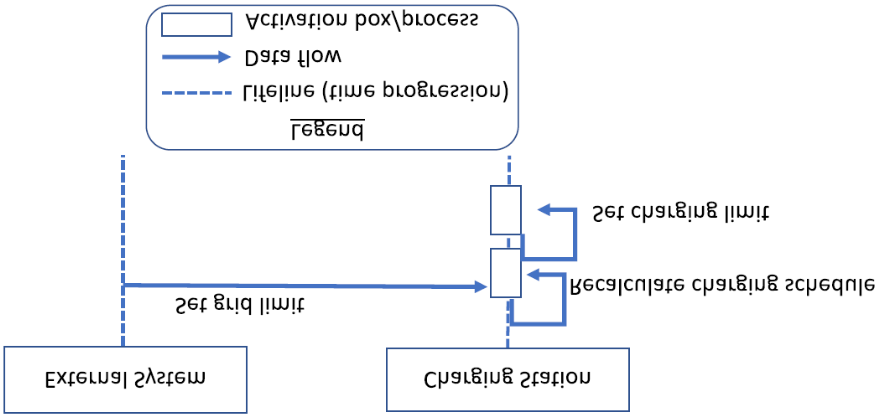


FIGURE 2. Example of modifying the charge rate through OCPP.

B. OPEN CHARGE POINT PROTOCOL

OCPP is one of the latest smart charge protocols for EVs developed by Open Charge Alliance. One of the recent versions, at the time of this research, is version 2.0 with bidirectional (charging and discharging) capabilities. The protocol allows for remote charging rate control, as well as other capabilities such as transaction management. Due to flexibility of the protocol, large amount of EVs may utilize OCPP or variant of OCPP soon. Even legacy standards such as ChaDeMo developed in Japan, are currently working to harmonize. Fig. 2 exemplifies the charge rate limit control through OCPP as defined in the specification. The external system (such as an Energy Management System) sets a grid limit to the charging station. Once the charging station receives the grid limit signal, the charging station recalculates the charging schedule to enforce the limit. However, since there is a delay time between setting the grid limit (charging limit specified from an external system) and implementing the actual charging limit, altering the limit frequently is difficult. Although not explicitly specified, if the external systems ends a new grid limit while the controller calculates the previous limit, the effects of the new grid limit may not take effect until the charge point imposes the previous limit. This proposes a unique challenge to utilizing EVs using charge rate limit control through OCPP: frequently adjusting charge rate is not possible; hence, many of the control schemes of the past research cannot be applied directly. For instance, if grid limit alteration requires 2 seconds to take effect on all EVs, the minimum control interval would be 2 seconds as well. implicitly observes this limitation.

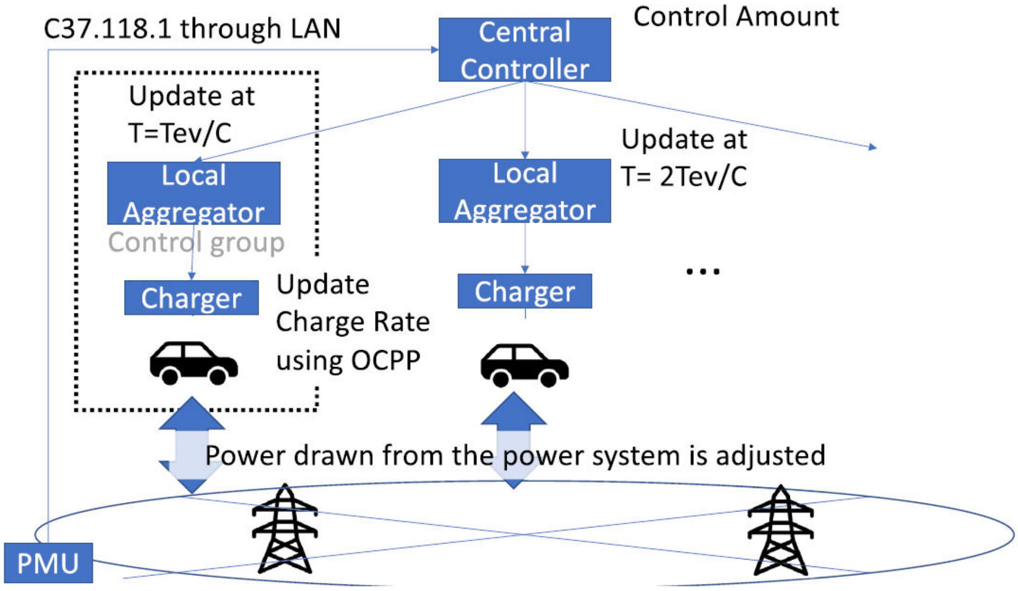


FIGURE 3. Overall architecture.

Although this does not propose an extreme consequence during large disturbances, where substantial amounts of support from EVs in a brief time is necessary, this limitation could be crucial for smaller disturbances such as net load variations. As a response to this limitation, the next section proposes a frequency control architecture as a remedy.

3. MODEL PREDICTIVE CONTROLLER WITH SYSTEMINTEGRITY PROTECTION SCHEME

A. OVERVIEW OF MODEL PREDICTIVE CONTROLLER

MPC is a widely utilized controller which computes an optimal control sequence for a predicted horizon every control interval.

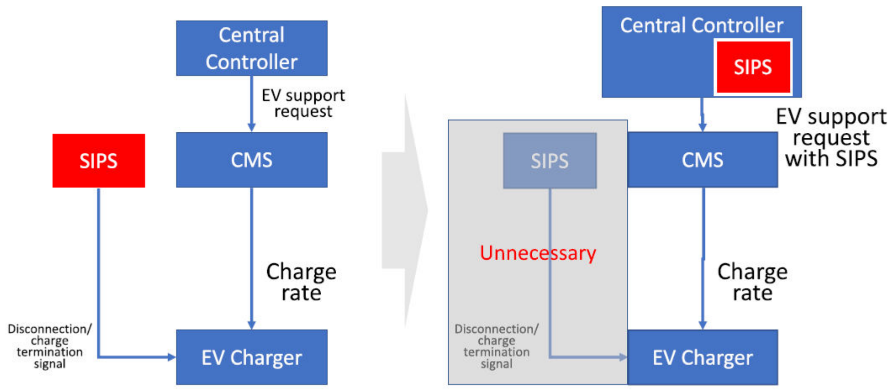


FIGURE 4. Incorporation of SIPS behaviour into the central controller.

$$\min \sum_{k=t+\Delta t}^{t+N\Delta t} (y[k])^2 + r\,(u[k]-u[k-1])^2$$

$$s.t \quad u^{min} \le u[k] \le u^{max}$$

$$x[t+\Delta t] = A_d x[t] + B_d u[t]$$

$$y[t] = C_d x[t]$$

Because the controller computes the optimal control sequence using an optimization engine, efficient utilization of control targets is possible. The following shows one example of a state based MPCV. MPC is widely considered simple to implement while offering sufficient performance and has been applied to various fields. Steps to implementation only requires (a) discretized model (b) objective function (c) selection of bounds (d) selection of

parameters. The principal behind the basic form of
MPC is relatively simple to understand.

1) The controller gathers measurements from the controlled system.
2) The controller computes optimal control sequences for the receding horizon.
3) The controller applies the first control step of the optimal control sequence to the controlled system.
4) Steps 1 to 3 are repeated.

As shown, the basic operating principal behind MPC closely follows the proposed architecture. Unlike conventional controllers such as PID, MPC is easy to implement and has implicit robustness given the model is sufficiently accurate.

B. PREPARATION OF INTERNAL MODEL

The MPC from earlier needs a state-space representation of Fig. 1 to function. First, an abstract representation of Fig. 1 is prepared as shown in Fig. 4. The model consists of two parts as seen from the disturbance side: plant and controller. The power system block treated as a plant; the hydro and thermal response are both treated as a controller; and disturbance and EV support combined into one disturbance .Using the abstract model, the sensitivity function between power system frequency (y) due to a combined change in disturbance and EV support (D) is

$$\frac{P}{1+PC}.$$

By removing the hydro reserve and thermal reserve, both of which are saturation blocks, the overall sensitivity function takes the following form,

$$\frac{\sum_{i=1}^{10} b_i s^i}{\sum_{j=1}^{11} a_j s^j},$$

where *bi* and *aj* are coefficients. Since the model is too complex to practically utilize, this research reduced the model to a 3rd order model using Hankel Singular Value. Fig. 6 shows one example of a Hankel Singular Value for reduction though, any reduction method should be sufficient. With a 3rd order model, the transfer function reduces to the form,

$$\frac{\sum_{i=1}^{2} b_i s^i}{\sum_{j=1}^{3} a_j s^j},$$

which is easily convertible to state-space form. Hence, the state-space representation of the internal model is,

$$\dot{x} = Ax + Bu$$

$$y = C_c x + Du.$$

Discretizing the model with a zero-order hold approximation, the discrete-time state space form then becomes,

$$x[t+\Delta t] = (I + A\Delta t)x[t] + (B\Delta t)$$
$$= A_d x[t] + B_d u[t]$$
$$y[t] = C_d x[t],$$

where *I* indicate an identity matrix. Furthermore, as outlined in Fig. 4, the formulated model combines disturbance and EV support as one input signal. Therefore, this model defines *u* as,

$$u = d + u^{ev},$$

where *d* indicates the disturbance. Hence, indicating that the solution to the MPC will always have an offset with respect to the desired signal. Internal processing removes this offset

C. SELECTION OF BOUNDS

The following two equations set the lower and upper bounds of the MPCV

$$u^{min} = P_{char} - P_{char}^{max} + d,$$

$$u^{max} = P_{char}^{min} - P_{char} + d,$$

where *Pchar* indicates the base charge rate of all EVs, *Pmax char* indicates the maximum charging rate of all EVs combined, and *Pmin char* indicates the minimum charging rate of all EVs combined. The base charging rate *Pchar* from above is,

$$P_{char} = N_{ev}\left(SoC^{max} - SoC_0\right)\frac{3600}{S_{base}\eta_c t_c},$$

where *Nev* is the total number of vehicles, *SoCmax* is the maximum State-of-Charge of one vehicle, *SoC*0 is the initial SoC, *Sbase* is the system base, _*c* is the charging efficiency, and *tc* is the time necessary for charge completion.

D. SYSTEM INTEGRITY PROTECTION SCHEME

To overcome the potential drawback of having more control groups, the central controller incorporates SIPS characteristics. Since requiring a separate communication pathway dedicated for fast response makes deployment overly complicated, this research incorporates SIPS into the central controller by altering the upper bounds of the MPC under a certain condition. Fig. 6 graphically overviews the approach.

1) ACTIVATION CONDITION FOR SIPS

Like most protection schemes, SIPS must remain silent unless the system detects an emergency. Two metrics determine an emergency condition,

$$f \leq f_{sips}$$
$$d \leq d_{sips},$$

where *fsips* and *dsips* are thresholds for frequency and disturbance magnitude. Recovery from this critical condition will automatically make SIPS silent, prompting a normal operation of MPC.

2) SIPS CONTROL EFFECT

When SIPS is enabled, signalling an emergency, the central controller alters the MPC bounds. Assuming adjustment of charging rates to zero during an emergency is allowable in power system operation, the central controller adjusts the upper bounds of the MPC as follows:

$$u^{max,sips} = P_{char} + d\,.$$

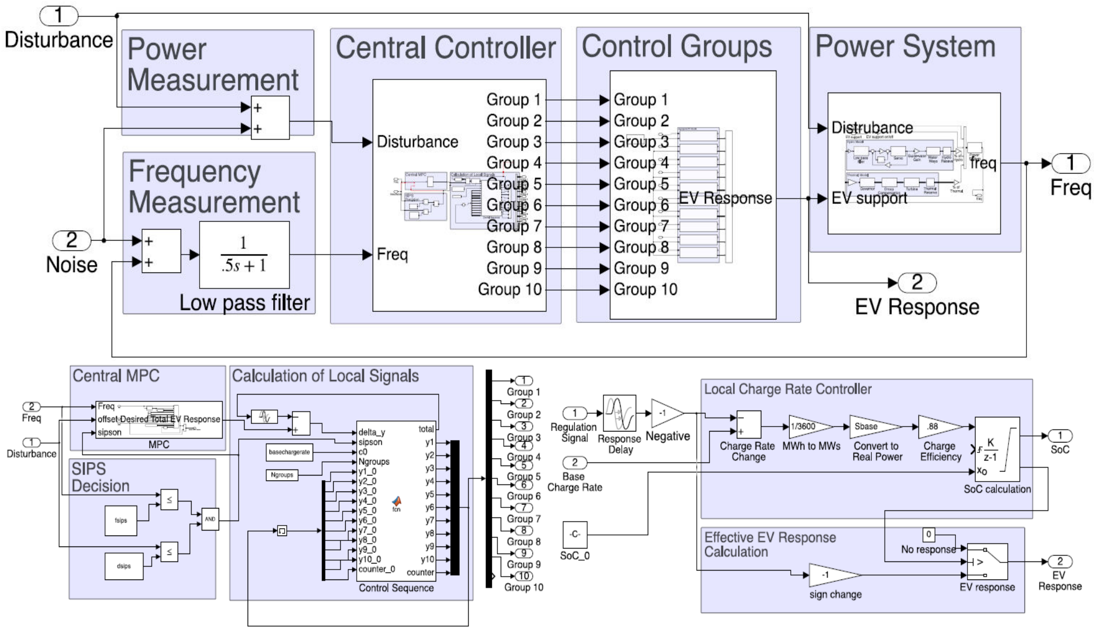


FIGURE 5. Simulink models. (a) Overall setup (b) Central controller (c) Aggregate EV within control groups.

4. GENETIC ALGORITHM Genetic algorithm is used to optimize the objective function of the given system which is mainly based on the search technique via operations observed in natural selection and genetics of the system. Genetic algorithms are more likely to converge to the global optima then conventional optimization technique, since they search from a population of points, and are based on probabilistic transition rules. The different GA operators are

Objective function

The objective function is to minimization the performance index which is the linear combination of the two area deviation of frequency multiplied by their respective bias constant and net tie-line power flow & of course, these variation are weighted together by a single variable know a ACE (area control error) of the respective power units i.e. differ for hydrothermal units. So fitness function to be minimized in this research paper is

$$J = \int_0^t (\Delta f_1^2 + \Delta f_2^2 + \Delta P_{tie12}^2)dt$$

Reproduction - Selection is the process of selecting the population from the current population which will survive for the next generation population for next process of the Genetic Algorithms. In this paper we select the Roullete Wheel selection process for the selection or reproduction of the next generation population. The brief study has been performed in past some decade.

Crossover - Crossover is also known as recombination of the population or reshuffled the selected population. Here, we select two random selected population & then we choose random site & interchanged the individual chromosomes with each other and finally produced the new off spring, and we proceed for next process. The performed analysis is studied.

Mutation - In this process, we select the individual bitrandomly and interchanged with '0' or '1'and it gives some variations in information of the population, although its probability rate is quite small as compare to cross over probability rate. The mutation and its application has been analysed.

EVs model

A large number of aggregated EVs due to their massive energy reserve can provide assistance to LFC of PS. A cumulative model of EV fleets revealed in Fig. 1b [2, 3] includes battery charger, primary frequency control and LFC. The battery charger regulates the power interchange between battery (Li-ion) and the grid. To avoid undesired frequency fluctuations in the event of all EVs disconnected from the grid, a dead band (DB) function with droop features is offered in each EV [3]. The value for upper limit (ΔFUL)/lower limit (ΔFLL) of DB is selected as ±10 mHz. The value for aggregate model droop coefficient (RAG) is taken equal to conventional plants. KEV and TEV are the EV gain and the battery time constant, respectively. KEV value is dependent on the state of charge (SOC) of EVs. ΔPEVs is the change in generation power of EV fleets with maximum and minimum power output limits of ΔPAG max and ΔPAG min, respectively, as given follows [2]:

$$\Delta P_{AG}^{max} = +\left[\frac{1}{N_{EV}} \times (\Delta P_{EV})\right]$$

$$\Delta P_{AG}^{min} = -\left[\frac{1}{N_{EV}} \times (\Delta P_{EV})\right]$$

where NEV denotes the number of grid connected EVs. For this study, in areas 1 and 2, 2000 and 9000 number of discharged EVs are considered, respectively. During LFC, the V2G or EVs output power ΔPEVs injected to the power network should be controlled based on ACE as (3) [3]

$$\Delta P_{EVs} = \begin{cases} K_{EV} \,.\, ACE, & |K_{EV} \,.\, ACE| \le \Delta P_{AG}^{max} \\ \Delta P_{AG}^{max}, & |K_{EV} \,.\, ACE| > \Delta P_{AG}^{max} \\ \Delta P_{AG}^{min}, & |K_{EV} \,.\, ACE| < \Delta P_{AG}^{min} \end{cases}$$

The charging and discharging capability of EV is believed within ±5 kW, though it may be up to 50 kW or more during quick start. KEV value changes with battery SOC level. It indicates the contribution of EVs in LFC. Here, KEV = 1 is considered for SOC range of 50–70% [2].

Optimisation problem

The foremost intention of the presented study is to certify slightest variation in frequency (ΔF) and tie-line power (ΔPtie) results following instant load perturbations in the studied PS models via the proposed controller and EVs. This aim may be achieved in terms of marginal settling time (TS), peak overshoot (OS), peak undershoot (US) and oscillations in ΔF/ΔPtie simulation results. For this, the controller must be optimised utilising a robust and efficient optimisation technique like ICA. For designing of the controller in the industry, frequently adopted objective functions (JS) are ISE, ITSE, IAE and ITAE [23, 30, 33]. The J given by (12) is used in the current optimisation task. The rest 3 JS are expressed using (13)–(15)

$$ISE = \int_0^\infty \{\Delta F_1^2 + \Delta F_2^2 + \Delta Ptie_{12}^2\} dt$$

$$ITSE = \int_0^\infty t\{\Delta F_1^2 + \Delta F_2^2 + \Delta Ptie_{12}^2\} dt$$

$$IAE = \int_0^\infty \{|\Delta F_1| + |\Delta F_2| + |\Delta Ptie_{12}|\} dt$$

$$\mathrm{ITAE} = \int_0^\infty t\{|\Delta F_1| + |\Delta F_2| + |\Delta P\mathrm{tie}_{12}|\}dt$$

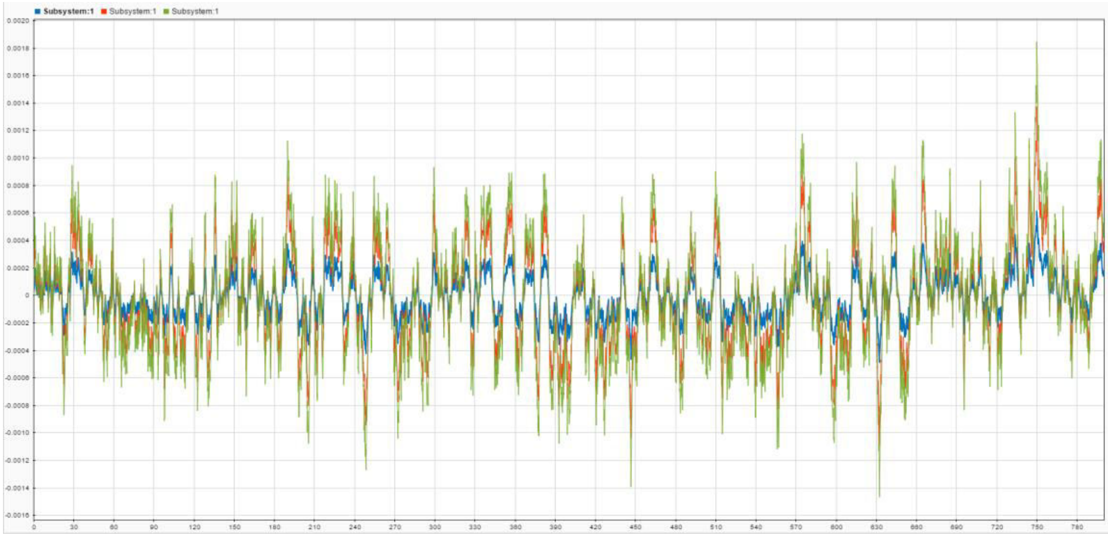
To advance the system performance, essentially J should be minimum. The values of (13)–(15) are calculated for performance comparison. However, the constrained optimisation problem for the tuning of CF-FOIDF controller is exposed to their limits. Hence, the optimisation task of the controller can be defined via

5. SIMULATION EVALUATION RESULTS AND OBSERVATIONS

Table. 3 overviews the summary of improvements with respect to a FOPID controller at *C* D 10. Overall, the performance of the proposed architecture and controller, on average, had a 22.05% reduction in nadir in the step disturbance test and 36.27% reduction in standard deviation in the load variation test. The proceeding text covers the detail of each test.

1) STEP DISTURBANCES

Fig. 9 and Fig. 10 are control signals and frequency response for 600k vehicles and 0.05 p.u disturbance for varying disturbance timings. Before inspecting the overview of the results, these figures provide insight into the results. Fig. 9 shows the example of control signals for 600k vehicles and □0.05 p.u disturbance for varying disturbance timings. Because the overall architecture is cyclic, there are vulnerable intervals in which the architecture cannot send the next control signal. The three different disturbance timing search highlight (a) directly after all control signals for all configurations (b) half a cycle after the control signal for *C* D 1 and (c) directly at the control signals. When comparing the three, the disturbance timing has minor impact on the control signals, unless *C* D 1. At *C* D 1, the difference in disturbance timing does play a significant role in delay timing variability which can vary between 0 to 2 seconds. This is verified in Fig. 10 where *C* D 1 responds the best when the disturbance timing is set to t D 12:0 (s). For a simple step disturbance, a faster response generally equated to better performance (a higher nadir).When comparing the control signals between the FOPID, MPC, and proposed, each at *C* D 10, FOPID had the slowest response, followed by MPC, and proposed. This slower response also propagated to the frequency measurements of the system as shown in Fig. 10. The faster response and smaller deviation of the system was expected from this evaluation as more charge rates are terminated; however, this also comes at a cost of a minor variation of control signals in the post disturbance state. Although the variations are minor, the behaviour does have a real-world implication of altering the charge rate of EVs. To what degree this may affect the EVs is unknown. At the very least, the inclusion of SIPS decision did not lead to an overshoot. Even without the SIPS decision, MPC performed better than FOPID, responding to events faster. This may be due to the ability of the MPC to determine the present decision based on predicted future states unlike FOPID.



In Fig. under a larger disturbance, the difference between the controllers and timing became minimal.

Of course, the introduction of SIPS decision in the proposed controller does exhibit a higher settling frequency and nadir. Apart from *C* D 1, the nadir and settling frequency are converged to the same value. At this magnitude, the complete termination of charging cannot fully prevent a blackout, but only reduce it, as the frequency would deviate too much for this architecture to support. Although the performance and characteristic of the proposed architecture under a step disturbance can be overviewed with these figures alone, a closer inspection of Table 4 reveal further insight.

Overall, all cases showed improvement from the reference (no control), FOPID, and conventional MPC (i.e., no SIPS decision) regardless of the number of EVs or disturbance size. As with the earlier figures, these results meet expectations for this case due to the faster responding nature of the SIPS decision.

CONCLUSION

The contribution as presented in the research addresses one practical approach to field deploying frequency control with EVs. Based on the evaluation, the proposed control scheme is viable, showing sufficient performance on major test cases. The relatively simple nature of the scheme is easy to understand, engineer, and deploy in comparison to a more complex control scheme and controller the main challenge was to keep the overall scheme relatively simple, while ensuring a significant performance increase. For instance, the alternative architecture combined with other types of controllers, such as sliding mode controllers, may offer superior performance, but the design of the controller would be much more complex. Despite the benefits provided, the proposed architecture has several limitations: these can be divided into the limitation of the architecture and limitation of the controller. The first limitation is the lack of resilience against a failure of the central controller. Although the current scheme is resilient against signal losses to the local controllers, this is not true about the central controller. Further consideration is necessary to overcome this issue. Another limitation lies within controller itself. As MPC was selected with respect to the relative advantage over LQ and PID controllers for performance, the robustness cannot be explicitly guaranteed. Furthermore, other forms of robust controllers and adaptive controllers were not compared, hence, there may be other suitable controllers. Furthermore, as SoC management was not the main focus of this research, further research may be possible into this direction, by utilizing the MPC's property of defining hard constraints.

SUMMARY AND NEXT STEPS

This research proposed a frequency control architecture of electric vehicles which utilizes Open Charge Point Protocol characterized by an asynchronous use of control groups. The proposed architecture provides frequency regulation through adjusting the charge limit of electric vehicles in each control group. Furthermore, to effectively utilize the proposed architecture, the designed model predictive controller incorporates a system integrity protection scheme behaviour. Through an evaluation on an aggregated power system model, the proposed architecture performed sufficiently for both large step-disturbances and load variations regardless of the number of electric vehicle groups present. All tests observed better results when more electric vehicle control groups were allocated in the architecture. In comparison to a tuned fractional-order proportional integral derivative controller, the proposed architecture and controller, on average, had a21.77% reduction in nadir in the step disturbance test and36.27% reduction in standard deviation in the load variation test.

With promising evaluation results, opportunities for use in other applications of the power system such as steady-state voltage control or congestion management are now a possibility. Future work includes designing a different central controller for these specific purposes to expand the use case of the architecture.

REFERENCES

[1] Y. Ota, H. Taniguchi, T. Nakajima, K. M. Liyanage, J. Baba, and A. Yokoyama, ``Autonomous distributed V2G (vehicle-to-grid) satisfying scheduled charging," *IEEE Trans. Smart Grid*, vol. 3, no. 1, pp. 559_564,Mar. 2012.

[2] F. Kennel, D. Gorges, and S. Liu, ``Energy management for smart grids with electric vehicles based on hierarchical MPC," *IEEE Trans. Ind. Infor- mat.*, vol. 9, no. 3, pp. 1528_1537, Aug. 2013.

[3] M. Datta and T. Senjyu, ``Fuzzy control of distributed PV inverters/energy storage systems/electric vehicles for frequency regulation in a large power system," *IEEE Trans. Smart Grid*, vol. 4, no. 1, pp. 479_488, Mar. 2013.

[4] S. Vachirasricirikul and I. Ngamroo, ``Robust LFC in a smart grid with wind power penetration by coordinated V2G control and frequency controller," *IEEE Trans. Smart Grid*, vol. 5, no. 1, pp. 371_380, Jan. 2014.

[5] T. N. Pham, H. Trinh, and L. Van Hien, ``Load frequency control of power systems with electric vehicles and diverse transmission links usingdistributed functional observers," *IEEE Trans. Smart Grid*, vol. 7, no. 1, pp. 238_252, Jan. 2016.

[6] S. Izadkhast, P. Garcia-Gonzalez, P. Frias, and P. Bauer, ``Design of plug-inelectric vehicle's frequency-droop controller for primary frequency controland performance assessment," *IEEE Trans. Power Syst.*, vol. 32, no. 6, pp. 4241_4254, Nov. 2017.

[7] N. Kariminejad, S. A. Taher, M. Shahidehpour, and K. Khateri, ``A hierarchicalgovernor/turbine and electric vehicles optimal control frameworkfor primary frequency support in power systems," *IEEE Trans. Smart Grid*, vol. 9, no. 6, pp. 6702_6712, Nov. 2018.

[8] M. Elsisi, M. Soliman, M. A. S. Aboelela, and W. Mansour, ``Modelpredictive control of plug-in hybrid electric vehicles for frequency regulationin a smart grid," *IET Gener., Transmiss. Distrib.*, vol. 11, no. 16,pp. 3974_3983, Nov. 2017.

[9] S. Iqbal, A. Xin, M. U. Jan, M. A. Abdelbaky, H. U. Rehman, S. Salman,S. A. A. Rizvi, and M. Aurangzeb, ``Aggregation of EVs for primary frequencycontrol of an industrial microgrid by implementing grid regulation& charger controller," *IEEE Access*, vol. 8, pp. 141977_141989, 2020.

[10] S. Debbarma and R. Shrivastwa, ``Grid frequency support from V2G aggregatorsand HVdc links in presence of nonsynchronous units," *IEEE Syst.J.*, vol. 13, no. 2, pp. 1757_1766, Jun. 2019.

[11] K. S. S. Ramakrishna, Pawan Sharma, T. S. Bhatti, "Automatic generation control of interconnected power system with diverse sources of power generation," *International Journal of Engineering, Science and Technology*, vol.2, no.5, 2010,pp.51-65

[12] Y. L. Abdel Magid, M. M. Dawoud, "Genetic Algorithms Applications in Load Frequency Control," *Genetic Algorithms in Engineering Systems: Innovations and Applications*, 12-14September 1995, Conference Publication.

[13] H S. Farook, P. Sangamasmeswara Raju "optimization of feedback controller power system using Evolutionary Genetic Algorithm"*International Journal of Engg. Science & Tech*; vol.3, No.5 May 2011

[14] O. I. Elgerd and C. Fosha, "optimum megawatt frequency control ofmulti-area electric energy systems," *IEEE Transactions on PowerApparatus and Systems,* vol. PAS-89, no. 4, pp. 556-563, Apr. 1970.

[15] N. cohn, " Techniques for improving the control of bulk power transfers on interconnected systems," *IEEE Transactions on PowerApparatus and Systems,* vol. PAS-90, no. 6, pp. 2409-2419,1971.

[16] S.M. Miniesy and E. V. Bohn, "Two level control of interconnected power plants*," IEEE Transactions on Power Apparatus and Systems*,vol. PAS-90, pp. 2742-2748, June 1971.

[17] Y. L. Karnavas and D. P. Papadopoulos, "Age for autonomous power system using combined intelligent techniques," *International Journal of Electric Power System Research,* vol. 62, pp. 225-239, 2002.

[18] R. K. Green, "Transformed automatic generation control," *IEEE Transactions on Power Systems*, vol.11, no. 4, pp. 1799-1804, 1996.

AUTHOR DETAILS:

Miss **MD SAMEENA** Received a Diploma in Electrical and Electronics Engineering from **Govt. Polytechnic Station Ghanpur** (Ghanpur), JANGAON (D)., B.Tech Degree in **Electrical and Electronics Engineering** from **JNTUH** (Mallareddy Institute of Engineering and Technology) Maisammaguda, Dulapally (post via Kompally) Medchal Malkajgiri (D), Telangana, India. And Pursuing **M.TECH in Electrical Power Systems** at Holy Mary Institute of Technology and Science, Bogaram(V), Medchal (D), Hyderabad, India in the Dept. of Electrical & Electronics Engineering.

Mrs. T. RAJESWARI received the B.TECH degree in EEE from Sridevi Women's Engineering College, V.N.Pally, College Rd, Gandipet, Telangana, INDIA, from JNTU University and MTECH in Electrical Power Systems in Tirumala engineering college, Bogaram (v), Medchal (D), Hyderabad, Telangana, INDIA. She has 1 year of industrial experience and 5 years of teaching experience. Currently pursuing Ph.D. at SR University and working as an Assistant professor in Holy Mary Institute of Technology and Sciences, Bogaram, Medchal District, Hyderabad, Telangana, INDIA in the EEE department. Her interest areas are FACTS, Computer aided power system analysis, electrical distribution systems, Power electronics, etc;