Renewable and Sustainable Energy Reviews 58 (2016) 1039–1047

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Review of recent trends in optimization techniques for plug-in hybrid, and electric vehicle charging infrastructures

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ARTICLE INFO

Article history:
Received 2 July 2014
Received in revised form
29 December 2015
Accepted 30 December 2015

Keywords:
Charging station
V2G
Optimization
EV
PHEV

ABSTRACT

For the consideration of environmental aspects of the personal transportation, electric vehicle (EV) and plug-in hybrid electric vehicle (PHEV) has the prospective solution nonetheless there is an obstacle to access the charging system plug. Additionally, the charging system delivers its own troubles when we compared it with petrol station since the participation of the different charging alternative. For the last few years, the studies associated with optimization of PHEV/EV charging infrastructure have drawn the researcher's consideration. New challenges and chances for the growth of smart grid technologies depend upon the recently introduced electric vehicle charging infrastructure services. In this particular review study, the literature bearing on the use of optimization methods for charging infrastructure is considered.

Contents

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http://dx.doi.org/10.1016/j.rser.2015.12.353
1364-0321/

1. Introduction

Recently the transportation sector reported nearly 25% of CO_2, which goes off over 55% of oil consumption around the human race [1]. Many researchers stated that in the transport sector has an excessive decrease in GHG (greenhouse gas) releases as well as it decreases the reliance on oil and gas [2]. Over the last decade, the implementation of hybrid electric vehicles (HEVs) has carried a noteworthy business concern. Therefore, newly presented work has a potential to increase the inclusive fuel competence by holding a higher battery capacity in plug-in hybrid electric vehicles (PHEVs). While, the outdated power grid, which could only benefit the electric vehicle to function constantly in "all-electric-range" (AER). The smart grid can own all of these schemes to connect with a stopper in HEVs. For instance, the implementation of electric vehicle could show the main role in an alternative energy integrative in a grid system [3]. To determine the present issues related to heterogeneous glitches with different purposes, there is a necessity of operative tools and algorithmic programs for smart electric grid technologies. While all these effective interactions took place within certain degrees of doubt and dynamism. It is stated that in the twelvemonth 2050, as per the statistic of the EPRI-electric power research institute throughout the (US) United States around 62% vehicle will encompass of PHEVs [4]. Additionally, there is a combined demand to apply this technology to the electric grid system. Whereas, there is a large number of PHEVs or EVs have the competence to endanger the steadiness of the power grid. For illustration, the society is to nullify the disruption when thousands of PHEVs are presented in the scheme within the least span of time, the load on the traditional grid will need to be accomplished much prudently. Foremost, the focal point of this study is to target and simplify the appropriate interface amongst the power system and the PHEVs, which is helpful to exploit the customer satisfaction and diminish the load on the grid [5]. To regularize the battery tons from a number of vehicles appropriately a control mechanism is desirable [6]. Due to alterations in the requirements of the PHEVs parked at a particular time span, the overall need will also have a significant influence towards the production of electricity [7]. Consequently, only well-organized business can guarantee strain minimization of the traditional system as well as improve both the electric power transmission and distribution. To insure proper development of electric vehicle manufacture, establishment of the charging station and battery-exchange should be established.

Optimization is a methodical process for discovering the top candidate solution that can be calculated either in a way to maximize or minimize the worth of a purpose from an exploration space by choosing the sum of specific variables [8]. Whereas, a number of scholars have practical dissimilarities of soft computational intelligence methods in contemplation to discover new solutions which could be reachable by the use of traditional methods in the domain of charging infrastructure optimization. Furthermore, it has been studied in the past few years that linear or non-linear optimization methods have been functional by the researcher to achieve the objective function. Though, most of the reviewed cases researcher found that either they can apply multi-objective or single-objective optimization. In line of this research paradigm, charging station for battery electric vehicle (BEV), plug-in hybrid electric vehicle (PHEV) and electric vehicle (EV) are from the same group as each of these types of vehicle needs charging infrastructure to charge the battery.

2. Contribution of this study

In the current research study, researcher main focus mainly lies on different optimization problems and the computational strategies employed for solving different issues related to PHEV or EV charging infrastructure. Prior studies in the domain of PHEV or EV mainly deal with smart grid integration [9], required risk management and economic dispatch of the large-scale PHEVs [10], the impact of PHEVs on distribution networks [11], architecture and energy management strategies [12] and Vehicle-to-Grid (V2G) and renewable energy source integration [13]. Few attentions were given on the optimization strategies and solution approaches, especially for various charging infrastructures. Higher penetration of electric vehicle depends upon successful deployment of charging stations [14]. In order to gain the main objective and fulfill the gaps in review studies of electric vehicles, this paper will focus mainly on optimization techniques and their use in solving different issues related to charging infrastructures.

This particular review study is organized into ten main units discovering diverse aspects in the paradigm of this research. In the first section researcher highlights the background of this particular paper. Whereas, Section 2 elaborates the problem in the arena of electric vehicles. The third section of this paper deals with the definition of different electric vehicles followed by the different methodologies for electric vehicle charging in Section 4. The following part-Section 5 offerings current development in the arena of electric vehicle charging infrastructure. Section 6 reviews the optimization targets and objective functions followed by different optimization algorithms. Thus, to optimize diverse parameters in the charging infrastructures by amplification the strength and weakness of each technique in Section 7. The critical discussion and finding in our review studies deals with Section 8. Ultimately, forthcoming viewpoints scheduled the usage of PHEV or EV charging system optimization be situated in Section 9 shadowed by finishing remarks in Section 10.

3. Plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs)

There are many alternatives which have been suggested by the researchers in command to reduce the dependence on the traditional fuel system by introducing the concepts like sustainable fuel sources, alternative transport solution etc. Among the alternative solutions of traditional vehicles, electric propulsion system-based vehicles have introduced considering the environment friendly choice in mind. Hybrid electric vehicles (HEVs) are immediately available on roads with the addition of traction motor which is electric as easily every bit on board storage system like batteries. The on-board computer memory system is different system architecture compared to traditional ICEV [15]. The upgraded and more pollution-free alternative of HEV is the plug-in hybrid electric vehicle (PHEV) that has on board storage system with these facilities of charging form power grid and renewable energy sources while parked. As a result, electricity replaces the fuel like gasoline, petrol. The final target in the revolution of electrification is to exclude the old fashioned internal combustion engine, hence AEV (All-Electric-Vehicle) start the new era. Furthermore, the two most recent all-electric types are fuel cell electric vehicle (FCEV) and battery electric vehicle (BEV). Whereas, the FCEV is driven by hydrogen, whereas BEV solely depend upon all its energy on the electrical power grid.

4. Charging of electric vehicles

PHEV or EV charging affects many parameters for instance, action of charging equipment, charging cost, power rating, time, location, and influences power grid on their existing. Fields like, distribution, standardization of demand strategies for charging stations, charging time and appropriate controlling measures are required to be spoke for the effective placement of Electric vehicle charging infrastructure [16].

Electric vehicles charging customarily ensue the charging zone in one's household. Whereas, with the Level-1 charging, electric vehicle is associated with home-attached garage for the purpose of slow charging. The Level-2 charging station is generally recognized as the principal method for battery charging for both public as well as private utilities and requires an outlet of 240 V. In Table 1 different kinds of charging power levels are summarized. Therefore, futurity technologies, focusing on the primary charging as well as the fast charging which can be executed in most cases [17–20]. Usually for Level-1 and 2 charging uses single-phase systems. Moreover, the DC is fast charging (Level-3) is built for private and public applications and it would operate just like a normal petrol station. For the purpose of 2 and 3 level chargers connected in shopping centers, hotels, parking lots, theaters, food shop, etc. are projected to practice by the over-all public charging stations [21–23]. Choosing an appropriate space for fast charging station can decrease this range anxiety [24].

4.1. Level-1 charging 'opportunity charging'

Among all available charging alternatives Level-1 charging is the most time consuming methods. Additionally, in United States, Level-1 charging uses as a standard 120 V/15 A single-phase outlet which is grounded, such as NEMA 5-15R. The connection may utilize the standard J1772 connector in the electric vehicle AC port [25]. The overall cost of a housing Level-1 charging arrangement has been projected around USD500-USD880 [26,27].

4.2. Level-2 charging 'primary charging'

In the line of Level-2 primary charging is the rudimentary technique for devoted the facilities for communal base and private. At present-day, the Level-2 equipment performs charging either 208 V or 240 V (at up to 80 A, 19.2 kW). Though, it required a dedicated equipment and a connection installation for household or communal charging station [28]. While, the electric vehicles such as the Tesla has the power electronics on board. Most of the household contains 240 V. Moreover, the Level-2 devices can load a typical electric vehicle battery overnight. The vehicle owners prefer Level-2 charging because of its faster charging time and standardized vehicle-to-charger connection. The overall cost of residential Level-2 is charging infrastructure setting up is around USD 150 [27]. For exemplar, the Tesla Roadster charging system has imposed added cost of USD 3000 [29].

4.3. Level-3 charging 'fast charging'

DC fast charging in the Level-3 could be connected to urban plus a highway refueling station which is comparable as, petrol

Table 1
Optimization methods, and diligence.

Author(s)	Year	Diligence	Optimization Methods
Rahman, I., Vasant, P. M., Mahinder Singh, B. S., and Abdullah-Al-Wadud, M.	2015	Hybrid swarm intelligence-based optimization for charging plug-in hybrid electric [70]	Hybrid PSOGSA
F. Malandrino, C. Casetti, C.-F. Chiasserini, and M. Reineri	2015	Vehicle A Game-theory analysis of charging stations selection by EV drivers [71]	Game theory
S. Yang, M. Wu, X. Yao, and J. Jiang	2015	Load modeling and identification for EV charging stations [72]	Ant Colony Optimization (ACO)
H. Yang, S. Yang, Y. Xu, E. Cao, M. Lai, and Z. Dong	2015	Electric vehicle route optimization considering time-of-use electricity price [73]	Learnable Partheno-Genetic Algorithm (LPGA)
Rahman, I., Vasant, P. M., Mahinder Singh, B. S., & Abdullah-Al-Wadud, M.	2015	Smart energy allocation strategy for charging stations of plug-In hybrid electric vehicles [74]	Gravitational search algorithm (GSA)
Y. Zheng, Z. Y. Dong, Y. Xu, K. Meng, J. H. Zhao, and J. Qiu	2014	Optimal charging/discharging strategy for electric vehicle battery swapping stations [75]	Linear Programming
J. Tong, T. Zhao, X. Yang, and J. Zhang	2014	Intelligent charging strategy for PHEVs in a parking station [76]	Non-dominated Sorting Genetic Algorithm II (NSGA II)
X. Yan, C. Duan, X. Chen, and Z. Duan	2014	Planning of Electric Vehicle charging station [77]	Hierarchic Genetic Algorithm (HGA)
Z. Zhu, S. Lambotharan, W. H. Chin, and Z. Fan	2014	Aggregated electric vehicles charging in smart grids [78]	Stochastic optimization
R. Tikader and S. Ganguly	2014	Energy management at municipal parking deck for charging of plug-in hybrid electric vehicles [79]	Differential Evaluation (DE)
F. Fazelpour, M. Vafaeipour, O. Rahbari, and M. A. Rosen	2014	Intelligent optimization to integrate a plug-in hybrid electric vehicle smart parking lot with renewable energy resources and enhance grid characteristics [67]	Genetic Algorithm (GA)
Shiyao Chen, Timothy Mount and Lang Tong	2013	Optimizing operations for large scale charging of electric vehicles [80]	UC and TAGS
J. Soares, T. Sousa, H. Morais, Z. Vale, B. Canizes, A. Silva	2013	Application-specific modified particle swarm optimization for energy resource scheduling considering vehicle-to-grid [81]	ASMPSO (Application Specific Modified Particle Swarm Optimization)
S. Xu, D. Feng, Z. Yan, L. Zhang, N. Li, L. Jing	2013	Ant-based swarm algorithm for charging coordination of electric vehicles [82]	ASA (Ant-based Swarm Optimization)
Wencong Su and Mo-Yuen Chow	2012	Performance Evaluation of Large Scale Plug-In Hybrid Electric Vehicle Charging Algorithm [61]	EDA (Estimation of distribution algorithm)
W. Su and M.-Y.Chow	2012	Computational intelligence-based energy management for a large-scale PHEV/PEV enabled municipal parking deck [6]	GA and PSO
F. Huang, P. Sarikprueck, Y. Cheng, and W.-J. Lee	2012	Design optimization of PHEV charging station [65]	Linear Programming (LP)
T. Ghanbarzadeh, S. Goleijani, and M. P. Moghaddam	2011	Reliability constrained unit commitment with electric vehicle to grid using Hybrid Particle Swarm Optimization and Ant Colony Optimization [83]	Hybrid Particle Swarm Optimization and Ant Colony Optimization. (HPSO-ACO)
W. Su and M.-Y. Chow	2011	Performance evaluation of a PHEV parking station using particle swarm optimization [7]	PSO (Particle Swarm Optimization)
Bashash S, Moura SJ Fathy HK.	2010	Charge trajectory optimization of plug-in hybrid electric vehicles for energy cost reduction and battery health enhancement [68]	NSGA-II
Ahmed Yousuf Saber, Ganesh Kumar	2009	Optimization of Vehicle-to-Grid Scheduling in Constrained Parking Lots [84]	PSO (Particle Swarm Optimization)

stations. Whereas, it usually functions with a 480 V or higher circuit of three phases [30] and it required an off board charger to supply regulated AC–DC adapter. The charging station of Level-3 is very less effective for residential surroundings. The standards for Direct Current plugs, as well as hardware are in improvement stage. Therefore, a Japanese protocol named as 'CHAdeMO' is fastest growing appreciation throughout the world [31]. However, the Setting up cost is a vigorous concern. In between 30,000 and 160,000 is the price of level 3 charging infrastructure [32]. Su and chow [33] who proposed an efficient energy management system which particularly cut down the overall of PHEVs charging in the fastest infrastructure that employ the added super capacitor and flywheel. He further used two batteries between 10 kwh and 15 kwh which demo the time of charging is around 15 min to charge from a minimum state of charge 20 percent up to the standard of 95 percent in the new structure of the computer simulations (Fig. 1).

Upkeep is one of the main cost factors of charging infrastructures [34]. Aggregate literatures statistics are available in numerous phases of the EV charging allocation approaches that contains both the upkeep and scheduling of numerous charging topologies [35–40]. Among all most of these works emphasize on the charging schemes for residential use. Furthermore, the Kulshrestha et al. [41] deportment research on past simulation result in energy management strategy (EMS) for charging of electric vehicle at car parks where heuristic optimization strategies for resolution of the effectual preparation are functional. Additionally, electric vehicle charging for community is also measured [7].The objective of their research mainly based on maximization of service quantity, whereas the overall energy cost is not measured in the proposed optimization. Whereas, Subramanian et al. [42] proposes a planning, optimization by means of an assortment of substitute power and power from the existing grid.

5. Charging infrastructures with dissimilar electric vehicles

In the road transport system, the charging infrastructure is an important parameter which is essential to improve and sustenance the successful diffusion of PHEVs or EVs [43]. Most recent studies of MIT- Massachusetts Institute of Technology, endorsing countrywide arrangement for electric vehicles appearing to be a better trial than making inexpensive batteries to power the cars [44]. Furthermore, the segment delivers an impress of the charging infrastructure charging system for domestic garage necessities for electric vehicles in single-detached dwelling, mixed-family system and business purpose.

These situations are described in the subsequent sections:

1. Charging system for domestic garage
2. Charging system for apartment complex
3. Charging system for commercial complex
4. Charging system for Renewable energy sources

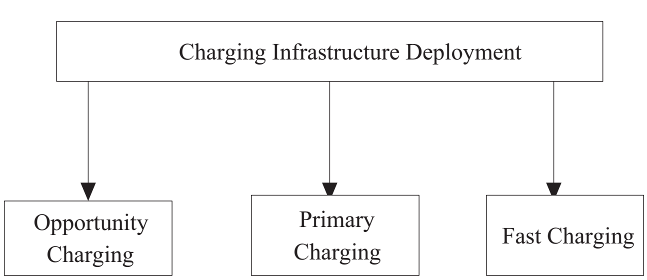

Fig. 1. Infrastructure of charging system.

5.1. Charging system for domestic garage

In order to mount electric vehicle charging system for domestic garage, it required a dedicated branch circuit from a prevailing house delivery board to a convenient passage or to a EVSE (Electric Vehicle Supply Equipment) is needed [45].

5.2. Charging system for apartment complex

The EV or PHEV charging fixing source in an apartment complex classically consists of installing innovative, dedicated branch circuits from the central meter distribution panel to either a suitable outlet or to a supply equipment.

5.3. Charging system for commercial complex

To an EVSE for Level-2 charging is used for a commercial complex parking lot usually it contains of new dedicated Electric vehicle charging installation branch circuits from the central meter distribution panel. Spacious parking lots offer a chance to control a fleet of electric vehicle in an intellectual way.

Venayagamoorth and Mitra specified that actual usage of PHEVs in parking zones to stop the transmission lines receiving loads and to act as shock observers when the wind power changes extremely [46]. A fuzzy logic based controller is suggested by the same authors [47] which receives the overall state-of-charge in a parking area. Whereas, the rapid demand and power generated from the wind provides control signals for charging or discharging of the electric vehicles. Nonetheless, the simulation studies on a twelve-bus system paradigm illustrates PHEVs charging and discharging as per the control signal, overloading of the transmission lines throughout high wind speeds can be averted by the wind power supply variations in the power grid can be reduced.

5.4. Charging from renewable energy sources

The aptitude of PHEVs or EVs to support the addition of renewable energy sources towards the current power grids system is possibly the utmost transformative that influence the electricity supply. Neumann et al specified that placement of photovoltaic (PV) large-scale accusing tackle in a parking lot is clarified [48]. Whereas, Letendre [49] research highlighted that a PV parking lot charging have a dissimilar commercial model to charge PHEVs or EVs with the help of solar power. While, Tulpule et al. [50] and Birnie [51] specified that finances and natural influences of Photovoltaic founded workplace charging station. The investigation exhibitions the technical option of a PV based office parking arena that benefits the landlord of the vehicle that is associated with the conveniences of household charging system. The researcher accomplishes that the landlord will get the reappearance of establishment and upkeep cost and profit within the lifetime of the photovoltaic boards. Birnie et al. [44], mentioned that a solar collector into a parking shadow would result in a much quicker pay-back-period, promising extensive setting up of solar capacity. Furthermore, Zhang in the year 2012 [52] explicate the intelligent control approaches that added both Electric Vehicles and Photovoltaic which composed the current electrical systems. There is a multiple benefit of presenting large penetration of PHEVs and PV instruments that is used to investigate by Denholm et al. [53].

This research originates toward an assumption that gives photovoltaic competence a provisional basis among the midday group capacity for PHEVs as well as deliver a message able load throughout low request periods (usually in the season before summer). Ingersoll and Perkins [54] clarify a 2.1 kW PV charging station mutual with the usefulness at Santa Monica. Zhu et al. offerings [55] an optimal charging control approach by stochastic semi-Markov choice process (SMDP) and progressive steady recompense has been envisioned using vehicle appearance fee probability. The scholar paradigm of the charging algorithm, presumptuous solar radiation as an incessant time Markov chain, influxes and removals of vehicle as similarly autonomous Poisson delivery and used putridness property of the Poisson process in order to find changes possibilities. The preference of the researcher is using Linear Programming (LP) technique to assimilate photovoltaic panel (PV) and Battery energy. They reflect only a photovoltaic board as a renewable energy source and circumvented other foundations similar such as hydro and wind.

6. Optimization target plus objective purposes

Optimization for charging purpose has at least four (04) steps:

– Identification of the place and their appropriate limitations
– Vehicle charging by using energy management strategy
– Objective purpose Assortment
– Assortment of a specific optimization for algorithm

To decrease about constraints such as installation or effective costs, life cycle cost of the charging station, and to maximize the average state of charge (SoC), total receipts, renewable energy origin desegregation etc. is the overall aim, of this research. Furthermore, intelligent power allocation monitoring, real-time simulation and smart charging policies have drawn much deliberation to the investigation communal.

Whereas, Kulshrestha et al. [56] recommend real-time intellectual energy management for the obtainable PHEVs to for the optimal usage of power obtainable, time of charging and stability of the grid. In addition, the gratification of the customer, circumstances of loads, battery and SoC are measured. Pang et al. [57] explained that the advantages of PHEVs and EVs as storing of energy for appropriate management of the demand side. Moreover, Herrera et al. [58] stated that the progress 'Hardware-in-Loop' simulation stage for both separate (communication networks) and unceasing (power electronics and power systems) is a parameter. Optimization of (LES) sizing the Local Energy Storage for charging infrastructure is conceived within a cost-minimization contextual bases said by Inoa et al. [59]. He further argued that LES and PHEV charging stations control mechanism is industrialized. All these research studies demonstrates that system with the optimized parameters improved during both the grid-connected and islanding modes and also throughout the provisional era with flows picking and minimized voltage. Therefore, Lu et al. [60] identified that the large scale studies on Charging Behavior, Charging station placement and driving pattern for (PHEVs) Plug-in hybrid vehicles. In conclusion, they recommend the requirement of real-world vehicle driving data and universal optimization based methods. The researcher avoids the renewable energy adding matter to encounter the future tests for large numbers of PHEVs market diffusion and their suitable charging abilities.

Su and Chow [61] specified that mathematical structure for the objective function is designed in order to exploit the general revenue on a vehicle fleet base is described. The researcher delivers the optimization objective and certain system constraints, as well as the simulated data. Rendering to the nature of the optimization difficulties, reflect on the paper, the authors suggest the Estimation of Distribution Algorithm (EDA) to control multiple batteries charging discharging from a clustering of PHEVs /EVs appropriately.

An algorithm, designated as modified Equivalent Consumption Minimization Strategy (ECMS) is future by Tulpule et al. to regulate the PHEV [62]. Whereas, this technique explains the local optimization difficulty by captivating into explanation the total energy ingesting factor at the same time upholding the battery SoC continual. Thus, the ECMS commands SoC as a continual orientation opinion with less ingesting of fuel. Researcher [63] describe the process of fast charging infrastructures fortified with renewable energy sources (RES) and energy storage to optimize the pattern of charging and selling power to the grid rendering to price differences to maximize the objective function that is a benefit of contributing in the electricity arcade. Rendering to Pan et al. [64], the objective function is to minimize the whole price.

Huang et al. [65] concept impartial purposes for the maximum utilization of renewable energy plus minimization of the charging price. The constraints used for the optimization are: storing the battery size and charging rate of the storage battery unit. According to Elgammal et al. [66], the purpose is to certify fast charging period of the battery deprived of overheating.

7. Optimization algorithms

Optimization glitches can be both mathematical function optimization difficulties and combinatorial difficulties. The first class of glitches can be divided in continuous optimization and separate optimization glitches. During incessant function optimization, the independent variables are real numbers, whereas for discrete function optimization, the independent variables can only be chosen from a predefined set of allowed and somehow ordered numbers [8]. The next Table 1 delivers some applications of optimization approaches used in the PHEVs infrastructure optimization.

One impartial purpose for optimization is when there is an additional multi standard or a multi-objective optimization problem originates. A multi-objective search as well as optimization problem is definite as any optimization difficulty that have more than one anticipated explanation or ultimate objective and all objectives are normally in struggle with admiration for each other, which means that there is no more optimal explanation [67]. In its place, there are sets of discussions or 'trade-off' near-optimal results that can be exploited founded on anticipated topographies that acknowledged negotiations amongst the objectives. Deliberating from scholars [66], the self-regulating battery charger controller is projected based on multi-objective particle swarm optimization (MOPSO) and gain regulating search algorithm. Prior studies utilized multi-objective optimizations and deliberate an optimal energy method for a PHEV or EV parking since the peak authorization, charging cost and the customer preference in. Whereas, a multi-objective optimization algorithm based on the Non-Dominated Sorting Genetic Algorithm (NSGA-II) for optimizing two objective purposes which are-minimization of fuel cost and total battery health degradation over a 24 h cycle is applied by Bashash et al. [68]. Although applying iEMS algorithm for optimal energy delivery seeing multi-objective optimization stated by W. Su and M.-Y. Chow [33]. Moreover, the researcher mentioned [7] that the submission of PSO-based technique in order to maximize the average SoC of PHEV with the restraints such as the battery capacity, cost of energy and loading time. Most of the researcher used PSO by upholding the strength of the algorithms for resolving complex and non-linear difficulty where a large amount of raw data desirable to be used. Researcher, presented the flow chart of PSO application, Objective purposes and graphs of parting and initial source for 50 and 500 PHEVs correspondingly and well ahead associated the PSO technique with IPM and GA. Even though they lectured the concerns of difficulties if additional impartial purposes are measured. Yet, the upcoming investigation guidelines for resolving multiple objective functions by means of weighted aggregation methods.

Cali and Ghiani [69] indorse Particle Swarm Optimization (PSO) method for an aggregator that maximizes the total proceeds of the fleet of vehicles and minimizes the power losses in the active dissemination network. Individually electric vehicle (EV) of the grouping means a set of sequences and later a constituent part of PSO algorithm. Total 200 EVs in domestic development are measured with graphs of dissimilar request summary. Two assessments are done between dissimilar recharge approaches in addition to amongst state of charge (SoC) variations of the EV aggregation. In addition, proper parameter settings are necessary in order to apply any specific met heuristic optimization procedure. In the line of any computational experimentations, it is significant to document parameter settings in adequate feature, henceforward rigorous repetition of experiments can be probable by the future scholars. Amplification the particulars of each optimization algorithm procedure is external the possibility of the current effort.

Prior studies in the last few year states that application of meta-heuristic algorithms such as Genetic Algorithm (GA) [6,67,76,77], swarm intelligence techniques such as Particle Swarm Optimization (PSO) [6,7,81,84], Ant Colony Optimization (ACO) [72,82], Gravitational search algorithm (GSA) [74] and hybrid optimization methods [70] are increasing in order to optimize dissimilar charging infrastructure parameters. Likewise, very newly a Game-theoretical analysis of charging station has completed by Malandrino et al. [71]. Table 1 shows various applications of selected optimization approaches from the year 2009 up to 2015. Further, most of the researchers apply single optimization methods, whereas few researcher deals with hybrid techniques and multi-objective optimization procedures detail are shown in the Table 1 underneath.

8. Results and discussion

Prior studies stated that most of the work was explored with the help of technical databases. For example the searching in SCOPUS was performed by using the keywords “optimization AND charging infrastructure OR charging station”, stemmed in 389 scientific literatures starting from the year 2008 up to the year 2015. The statistics of the documents for exact keywords are shown in Fig. 2. Thus, from the past literatures regarding the area of optimization in charging infrastructure, it appears that application of various optimization techniques is still in its premature stage. More than 75% of the studied literatures for searching keywords have been available in the last four years, giving a prospective for an upcoming incorporation of various optimization methods towards the domain of electric vehicle charging arrangement optimization.

Very recently, vehicle-to-grid (V2G) technology appears to be a promising field among the research community of electric vehicle study. There are some key issues such as charging infrastructure based on bi-directional communication and insufficient business concept as well as financial justification force the delay of the actual implementation of V2G [43]. The vehicle-to-grid (V2G) idea joins two greatest noteworthy technical sectors – the electric power sector and the traditional fuel-based transportation sector – in a way that may report substantial complications in both. Electric vehicles could lessen the emission of greenhouse gas and mitigate both the pollution and security problems related to oil importation, removal and combustion by both receiving and supplying power to the power grid. It could also enhance the total outcome of the power sector and produce more revenue to the vendors of electric vehicles [61]. Nevertheless, there exist barriers between social and technical aspects that delay the instant understanding of these possible benefits.

Previous literatures that deals with the optimization of electric vehicles charging infrastructures are mainly founded on various models, possibly because of the inadequacy of real systems of a suitable dimension for the study. Very few solo EV proofs of concept experimentations have been carried out for vehicles with V2G capability. However, no systems level realistic assessments have been performed. Earlier literatures that deals with numerous models can be categorized into (1) hourly models (time-series) and (2) long-term models (system scale planning) [85]. There is a need for the control of both charging-discharging to the traditional power grid in order to perform economic operations of the electric vehicles in the V2G approach. The associated works emphases broadly on different smart approaches for optimum scheduling and charging of electric vehicles. To increase the revenues from grid dealings established on the price of electricity, the overall output power levels and charging–discharging times are planned intelligently [86] and consequences of grid failures on V2G are also shown. In order to schedule the vehicles, Binary Particle Swarm Optimization (BPSO) technique is used and the outcomes show that advanced control and safety are required to get rid of any adverse effects caused by the large bidirectional power surges to the batteries and the inverters of the individual plug-in vehicles. An approach to enhance the charging of electric vehicle behavior with the aim of curtailing the costs of charging, attaining a reasonable state of energy levels and optimal balance of power is defined by Sundstrom and Binding [87]. Results show a linear programming method is enough in considering electric vehicle

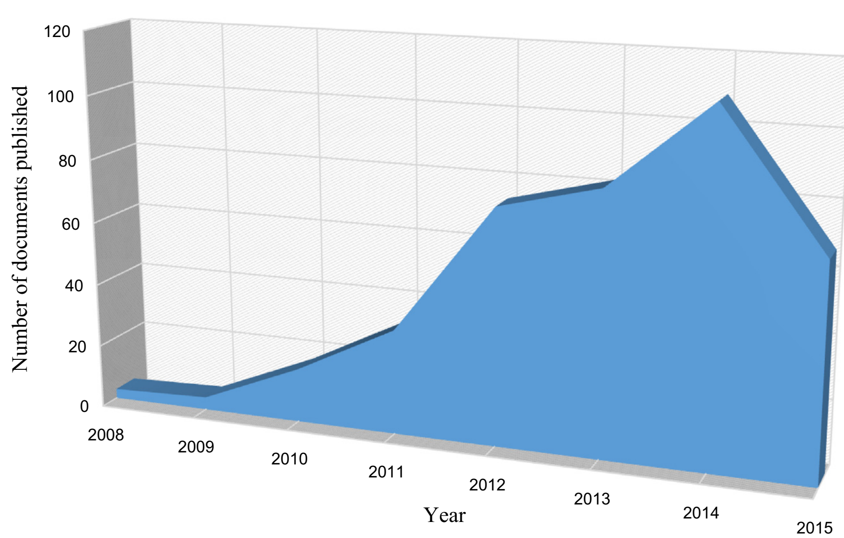

Fig. 2. Selected papers explored using the scientific database.

charging optimization. An optimum control approach based on discrete Particle Swarm Optimization (DPSO) is offered by Hai-Ying et al. [88] to find out the appropriate charging and discharging times for electric vehicle fleets for a particular load curve. All the constraints are decided by battery characteristics and as fixed by vehicle owner. Outcomes indicate that this V2G system aptitude does develop the load curve under the method.

A V2G configuration is familiar [89] to optimally allocate both the energy and subsidiary services for the maximization of the revenue to aggregators while giving easiness and peak load shaving to the utility and low charges of electric vehicle charging. The construction of driving patterns is used by the help of data from year 2009 National Highway Travel Survey for houses from Texas town. The results indicate that optimization algorithm offers noteworthy financial benefits to the consumers and aggregators for different battery replacement costs providing additional system.

The overall energy management system requires to enable fixed optimization, predictive optimization, multi-objective optimization and dynamic optimization [43]. Table 2 explains the optimization types that are specified underneath.

Different types of optimization techniques used for charging infrastructure optimization have explained so far. This research study elaborates the scholars that are trying to build effective control systems for charging infrastructure in order to simplify upcoming PHEVs or EVs diffusion in the main road. The suitable charging infrastructure and management system of station can pledge the larger penetration of electric vehicle. For the upcoming development of the transport industry, which solely depends up on electrification from a proper charging infrastructures.

9. Future directions

This section proposes a future research direction and measures for the optimization of PHEVs or EVs charging infrastructures. This specific field of research is relatively fresh and probable future outlooks have to be emphasized, so that novel methods can be comprehended.

9.1. Optimization techniques

Possible features of the prospective optimization techniques are discussed underneath:

Numerous optimization methods include evolutionary optimization algorithms, direct search techniques and other techniques which don't require function derivatives calculation. Whereas, most of the researcher have chosen the suitable algorithm which depends upon multi-objective capability provided for multi-criteria optimization to solve the specific difficulties.

- Charging infrastructure efficiency is one of the key performance indicators for effective diffusion of EVs. Different types of sensors are required for charging optimization and automatic detection of State-of-Charge (SoC). So, researchers should design and construct metaheuristic techniques for this purpose.
- Both the exploration as well as exploitation [104] of optimization search areas are crucial for finding the desired result.
- Technologists from multi-disciplinary fields should come forward to implement the theoretical knowledge. Researchers and engineers from diverse backgrounds like Control system, architecture, civil, mechanical and electrical engineering should play a vital role together in order to make PHEV integration in smart grid successful.

Table 2
Optimization types.

Type of Optimization	Example
Fixed	Single-objective optimization given a certain constraints [90–93]
Multi-objective	Multi-objective energy scheduling: minimizing energy usage, minimizing peak demand, minimizing charging cost, maximizing customer preference, etc. [94–98]
Dynamic	Plug-and-play operation [99,100]
Predictive	Time step ahead prediction [101–103]

9.2. Intelligent management of charging infrastructure

Demand Side Management (DSM) is stated by the Department of Energy (DOE) [105] as “Changes in electric usage by end-user customers from their normal consumption patterns in response to changes in the price of electricity over time, or incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.” Thus, the DSM programs should be implemented into the existing Intelligent Energy Management System (iEMS) model for the avoidance of blackout and voltage sag hence maximize the financial benefits. Furthermore, this under-exploited capacity could successfully power a nationwide fleet of electric vehicles with a little increment of the power capacity of the traditional grid setup [106].

9.3. Cost and performance trade-off

In view of price and presentation properties for the market success of electric vehicles, fitness functions are formulated in order to curtail the cost of drivetrain and performance of driving necessities are nominated as variables to guarantee that the PHEV or EV overall qualities are not surrendered during the process of optimization. One of the key components of an electric vehicle (EV) is an on-board battery which decides its total capital cost as well as performance [107]. Consequently, the core part is too influential the cost efficiency of EVs is principally one of ascertaining part of the upcoming route of battery cost and enactment.

10. Conclusions

The focal point of this particular review study is the computational and algorithmic aspects of various optimization techniques. Whereas, researcher discusses a chosen set of publications (2008–2015) in Table 1 to play up some of the beneficial solution methodologies. To better understand the strength and weaknesses of optimization methodologies it is very crucial for designing the effective charging system for PHEV or EV. For achieving this, the researcher is demanding to project the controller for charging infrastructure and numerous literature on the optimization-based techniques were brought out. Though, these particular kind of vehicle will help the lawful agencies in its part to enhance the energy and environmental security and it will also help to successfully market to consumers. Furthermore, the researcher highlighted the point that in order to promote carbon- free transportation sector, charging from renewable energy sources should be given preference compared to household, apartment complex and commercial complex. Therefore, the proper integration of diverse renewable energy source for charging electric vehicles is the future of the charging infrastructure optimization. The foremost determination of this review study is to provide a wide insight on various optimization strategies for PHEV or EV charging infrastructure. In a nutshell, it is concluded that future researcher should apply effective algorithms in order to resolve issues related to electric vehicle charging. The future direction of this study declared that, solar energy charging stations could be a focal spot on forthcoming infrastructure investment. Whereas, the impact and interaction between solar energy and EVs is another area requiring detailed analysis, as a solar charging station.

Acknowledgment

The researcher wants to acknowledge Universiti Teknologi PETRONAS (UTP) to conduct this research study under Universiti Teknologi PETRONAS Graduate Assistantship (UTP-GA) scheme.

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