Journal of Intelligent & Fuzzy Systems 43 (2022) 4395–4407
DOI:10.3233/JIFS-220089
IOS Press

An advanced electrical vehicle charging station using adaptive hybrid particle swarm optimization intended for renewable energy system for simultaneous distributions

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Abstract. A proposed hybrid approaches are incorporated in Electric Vehicle (EV) fast charging station (FCS) using (RES). Hybrid approach is improved by Adaptive Hybrid Particle Swarm Optimization (AHPSO) named as AHWPSO, moreover the proposed work Grey Wolf Optimization (GWO) is assist with adaptive hybridize PSO algorithm. Therefore, an overall pricing cost should be reduced maximum Electric Vehicle Charging Station (EVCS) with minimal installation. This simulation work is verified an adaptive time varying weightage parameters to increase the AHWPSO particle diversity factor. Proposed algorithm is incorporated with improve the novelty, and compared the results are recent version of PSO used for EVCS. Its increase the charging ability, energy loss minimization, voltage deviation reduction, and cost minimization. A distribution micro-grid capacity and demand are tested. Similarly, low to peak period energy variations are controlled by proposed algorithm with reduced capacitor bank. Overall control algorithm code is executed buy MATLAB/Simulink platform, the performance of this work listed, and compare to the existing approaches with achievement of maximum efficiency.

Keywords: Electric vehicle, renewable energy sources, adaptive hybrid PSO, grey wolf optimization, grid

1. Introduction

Due to the issue of fuel/diesel demand and cost-range concerns, the fast charging options are quickly increasing in EV's stations in all over the world [1]. Fast Charging Stations (FCS) have recently become critical in the EV sector for the deployment and attractiveness of electric cars [2]. Smart parking lots with FCS are being designed to meet the demands for maximum rate charge [3]. At the moment, the typical FCS contains a 50-kW charger, and the standards consider larger power ratios of up to 240 kW [4]. In the future, EVCS time is predicted to be decreased to a few minutes [5]. Currently, numerous places with varying operating aims sluggish with quick charging activities are being carried out [6]. Car-parks are used for slow charging since EVs are anticipated to stay in them for an extended period of time [7]. As a result, smart charging plans are offered by time-varying solutions that reduce the costs of charging parked vehicles while also supplying energy to the micro-grid with flexibility [8]. The EV's energy management is used to reduce total electric vehicle charging costs while it is also utilizing the collective flexibility of electric cars in grid to vehicle and vehicle to grid operating systems [9]. Fast charging events are often distinct from ordinary time-variation charg-

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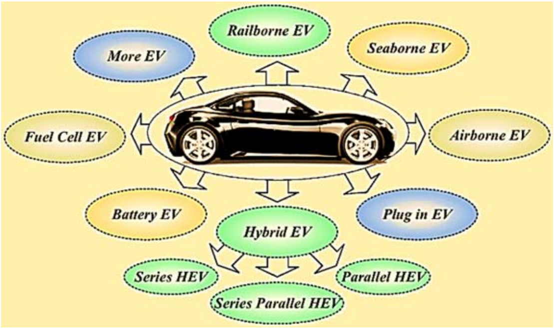

Fig. 1. Types of EV.

ing [10]. Time-variation charging is accomplished by the use of sources such as grid electricity, and Energy Storage Systems (ESS) [11]. An illustrated in Fig. 1 shows that battery alone represents as source in the EV, fuel cell-battery assisted EV, battery incorporate hybrid EV, and a battery - grid (or) external charging station by using the plug in EV.

Time shiftable charging is not achievable to meet the demand for higher-power rates since rapid charge stations cannot be connected to peak demand times [12]. The main challenges with rapid charging are FCS inadequacy and expensive installation costs [13]. The most rapid charging structure [14] satisfies conditions like as coverage and demand levels. The FCS has the disadvantage of being unable to interface with a balanced geographical distribution of stations [15], as well as the high cost of land in metropolitan locations. Furthermore, storage and renewable energy sources (RES) are limited in FCS; putting huge but distant stations may not be a viable option, as it would cause major power quality concerns on micro-grid bases, extending the driving distance for fast charging stations in high-traffic locations [16]. One of the most difficult aspects of FCS is locating it where there is a significant volume of traffic. Important aspects such as operational expenses and customer satisfaction are taken into account while choosing a site.

FCS has a different purpose than parking lots [17]. The quality of service measures, which are dependent on the delay time and blocking frequency that should be a significant aspect in the FCS's achievement [18]. Other FCS challenges include charging ports, waiting areas, and the availability of electricity to charge, all of which offer power allocation. RES sources are used in the grid for reasonably quick charging and mitigating grid overload [19]. Though the cost of constructing renewable energy infrastructure is low, power density and variations cause the rapid charging process to be delayed. For rapid charging electric vehicles, ESS is used to reduce power fluctuations and reduce peak demand [20]. The optimal location and sizing of EV fast charging stations and RES's are discussed in this proposed research using a hybrid optimization method. GWO and upgraded AHWPSO are combined in the proposed hybrid technique. It's known as the adaptive hybrid PSO method.

This proposed study describes, how to charge EV in hybrid battery charging using a stochastic AHWPSO swarm based algorithm on a micro-grid RES. The GWO approach is meant to address the optimization issue of grid demand by creating the greatest output power. Because the PV system's irradiance and temperature variance power monitoring is done independently by using MPP tracking, and wind is depends on the environmental factor with minimum number of wind speed. The MPPT control scheme is used to regulate the battery's charge. The efficiency is calculated by the computation and consideration of mathematical models and ideal switches of all components, mostly because of the use of real models. An AHWPSO model with a PV array/ wind was built the modelled and simulated. The charging station has a capacity of 1 kW. The proposed design took into account two primary units: modelling of the system and cost minimization.

The simulation results were produced using the MATLAB/Simulink or m-file software packages. It planned 1 kW charging station will also be subjected to an economic examination to verify its viability. The proposed research is restructured as follows, section 2 represents the recent research work, section 3 describes the overview of proposed work implementation, section 4 illustrates the AHWPSO algorithm based allocation RES/FCS approaches, and section 5 demonstrates the simulation results and discussion. Finally, section 6 concludes the proposed research work, and future scope.

2. Recent related research work

Based on this section precise conversation about fast charging station electric vehicle for demand distribution for implementation work with various control, and optimization algorithms discussion. The purpose of this literature is analysis the performance, and demand of proposed EV FCS. Present an EVCS placement and capacity model based on the prediction of EV fast charging demand distribution already predicted [21]. Charging stations, as an important aspect of the electric vehicle (EV) sector, have a significant impact on customers' willingness to utilize EVs [22]. A well-chosen charging station site and capacity plan may not only decrease the cost of investment and power grid hazards, which will provide EV users with easy charging services [23].

Recently, there was an increase in interest in the planning of electric vehicle charging stations. These studies' goals may be divided into two categories: 1). lowering planning expenses; (2) keeping up with billing expectations [24]. Primarily evaluated the construction cost of charging stations and proposed a charging station placement and capacity planning technique with the goal of minimizing planning expenses.

Reference [25] developed an optimal charging station planning model to reduce the total of construction and network loss costs. MPPT is a technique for getting the maximum power out of a solar panel in actual situation. Various predictive and evolutionary algorithms can be employed to properly identify the MPP to increase MPPT proficiency [26]. BAT search technique was utilized to create the PI tuned controller incorporate with MPP tracking. MPP can also be determined using techniques such as PSO and GA [27]. For effective MPP determination and DC motor speed control, PI controllers with artificial bee colony optimization are utilized [28]. The proper selection and sizing of EVCS is one of the primary problems.

In this proposed system is used of EVCS to limit the negative impacts on power networks, according to a review of recent scientific work. The FCS can help with the charging time issue, which is a critical component of EV adoption and deployment. FCS charge electric vehicles as rapidly as gasoline stations, and they play a key role in expanding travel distance. One of the concerns with installing FCS is that it increases the voltage drop in the electric network [29]. Because research on electric vehicles and charging stations is still in its early stages, the literature on EV allocation is restricted. There are lot of literature on the EVCS allocation taking into account the uncertainty of electric vehicles. Furthermore, the majority of current research does not offer the distribution network along the road network for suitable EVCS allocation. Several research missions have also set aside charging stations in adjacent sites that might not service all users in a region. The majority of research based on EV minimizes the power loss, however it varies depending on the load of the EV. As a result, reducing power loss does not give the ideal allocation. Rapid charging stations are being considered for the distribution of EVCS in many recent works, although not all electric cars are well-suited to the facility of fast charging. As a result, an optimal solution for quick charging is more important. These disadvantages and motives motivate me to conduct this research.

3. Proposed work

The main objective goal of this study is to reduce the total cost of a charging station's construction and operation, as well as the loss cost of EV users on the route to the charging station and the micro-grid's network operating either AC or DC grid output without any additional losses [30]. Objective function is to,

$$mF \text{ cost} = F_1 + F_2 + F_3 \tag{1}$$

$$F_1 \text{ (Energy loss)} = E_{loss=} \sum_{T=1}^{24} P_{loss}(T) + \Delta T \tag{2}$$

$$F_2 \text{ (Voltage deivation)} = V_{D=} \sum_{T=1}^{24} V_D(T) \tag{3}$$

$$L_c \text{ (Total cost)} = V_{D=} \sum_{g=1}^{n_l} \gamma_n \tag{4}$$

Where mF cost is annual cost of EV station, F_1 is annual operation and construction cost of EV station, F_2 is annual total losses cost of EV user on the way charging station, F_3 is annual network loss cost of power grid. E_{loss} is energy losses, P_{loss} is power losses (incusing line and charging losses), T is regular working time of EV station, γ_n is auxiliary investment of co-efficient, and V_D is voltage deviation, L_c is total cost. Total number of chargers in a charging EV station is connected, it is not only the number of EV's in a line, which is consumers agree while waiting the EV stations. The fast EVCS demand is calculated as per number of total EVCS [31].

The EVCS numbers of charger is estimated as follows:

$$\text{Number of charging station} = N_{i=} \left[\mu_i \sum_{\frac{j\varepsilon J_{cni}}{n_s}} n_j \right] i\varepsilon J_{cs}. \tag{5}$$

Where μ_i probability of EV consumers is arrives at charging station, 'i' is same time, n_s is number of EV

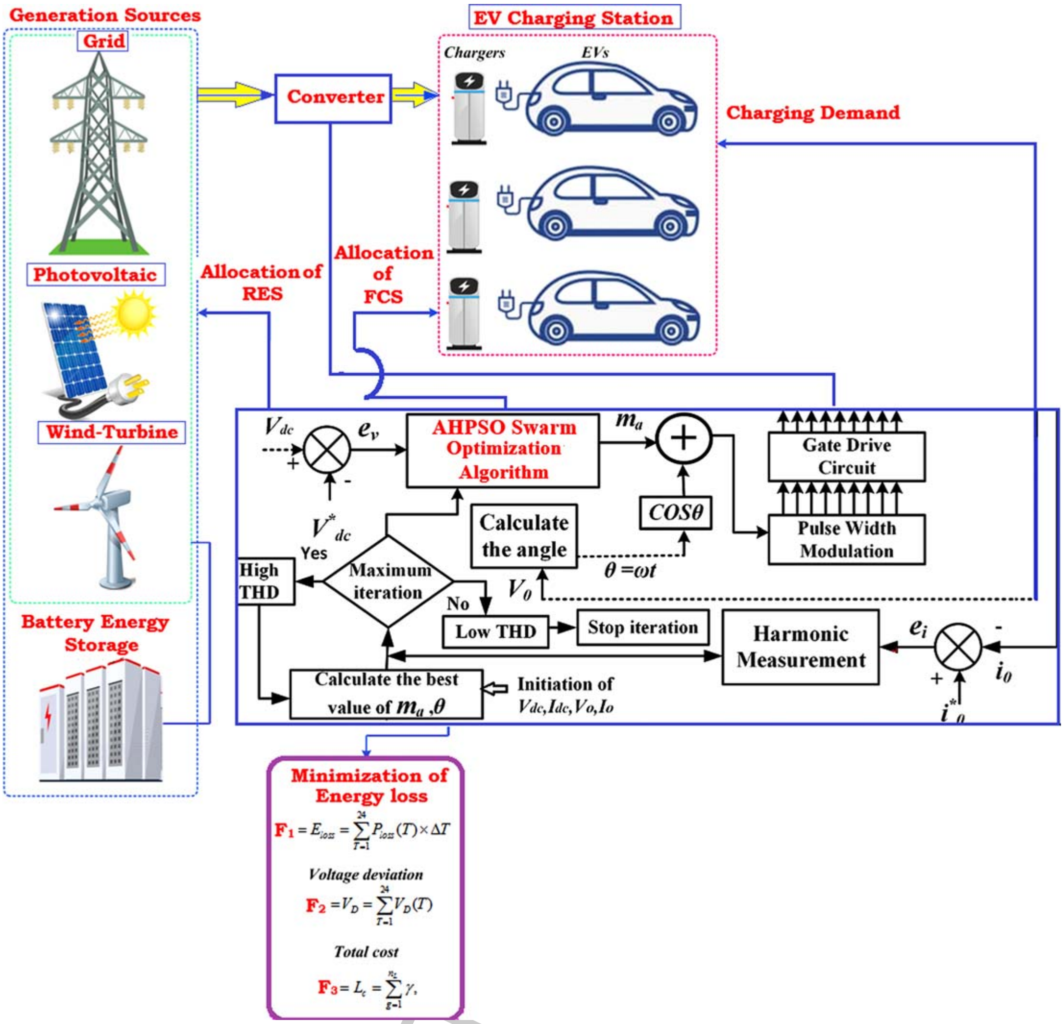

Fig. 2. Proposed EV configuration using AHWPSO algorithm.

stations in a queue, which can be accept by EV consumers. J_{cs} is set of EVCS. J_{cni} is set of coaction of fast EVCS demand points located service area [32]. Figure 2 shows that the schematic diagram of EVCS with RES. Proposed work is focused on allocation of EVCS and RES at initially started on equal time operating conditions. To allocate the RES and EVCS is get optimal solution, because an efficient AHWPSO with aid of GWO algorithm was presented. The combination of two optimization hybrid algorithms are improved energy output power, its minimized voltage deviation, energy losses, and cost minimization functions.

The suggested technology reduces voltage variation to produce a high voltage profile. The improvement of weightage allows for the exploitation of maximal EV at the lowest cost of EVCS. Assumed that the charging station is provided in a distribution method to meet the demand for charging at a nearby place. Uncertainties such as the deviation route and PV uncertainties of control system may identified. Wind is used to predict the EVCS demand. The modelling of uncertainty is based on distribution functions that enable realistic functioning. The computational effort and time consumption are difficulties caused by the uncertainty. The AHWPSO is used to solve the problem of uncertainties and gives maximum convergence speed, the ability to drive the optimization, and a smaller number of control parameters.

The proposed design is consist of 1 kW Solar-PV system, 0.6 kW wind turbine generators are operating parameters in this study as shown in Table 2. Several study points concerned/deal with the benefits of combining a battery storage system with PV

Table 1
Typical values of system and operating parameters

Description	Parameter values
Charging station capacity	1 kW
Solar capacity	750 watts
PV open circuit voltage & current	75 V & 8.21A
PV short-circuit voltage & current	68.9 V & 7.51A
Wind capacity	1 kW
Grid capacity	1.5kW
Converter unit input	100V
Converter unit output	160V
EV battery capacity	30Ah
EV charging current/Discharging current	32A
AC line voltage	230V
DC bus voltage	110V
DC charger power	0.5 kW

to achieve steady electricity at low operational costs. In this dissertation, a micro-grid is formed by connecting a battery storage system to PV panels and the main grid to supply electricity for EV chargers. PV, BSS, grid, and EV chargers all require independent power converters. In hybrid power source EV charging, either DC/DC converters into a common DC bus, then connected to the grid via a bidirectional AC/DC converter (DC micro-grid), or a common AC bus with separate stage rectifier for each source in the EV charging station (AC micro-grid) or in a micro-grid that is both operating under AC and DC voltage as shown in Fig. 3.

The instantaneous measurement of energy per unit time is known as power. The quantity of power consumed would be determined by the amount of current flowing into the battery at the moment, as well as its voltage. Energy is very simple to calculate. Proposed battery store 12*30 Ah/1000 = 0.36kWh of power, it is half discharged 0.18kWh. Which is needed to minimum level of proposed model, because some losses are identified. The power consumption is depended to fast discharging /charging pumping system of battery unit.

The efficiency level is mandatory to maintain 50 to 90% Therefore, the charging battery is completed in 10 hour, then find out watts 0.36kWh/10 = 0.036kWh. The EV's provide information about their electrical parameters, such as battery capacity level, charge rate, and State of Charge (SoC), therefore the local aggregator under the centralized control strategy as shown in Fig. 4. Each local aggregator enters into a contract with the grid operator based on the aggregated energy demand. After that, the aggregator use proposed algorithms to achieve its intended goals while meeting the needs of EV users. To accomplish this all set points will be sent to the CP's via a communication system. The control unit within each CP receives the command signal and runs the charger/inverter to provide the appropriate charge/discharge power. The combination of hybrid optimization is used to control the converter switching method. Hence, AHWPSO with incorporate GWO algorithm are generated the optimal switching angle and duty cycle signals to converter unit (both AC-DC, DC-AC). The specific area is classified into distinct zones based on charging demand and vehicle density. The EV's placement is defined by the slow and rapid charging modes. The suggested AHWPSO strategy addresses the EV charging demand, and it's to find input RES availability. Which is help to utilized of the allocation in RES and fast charging stations.

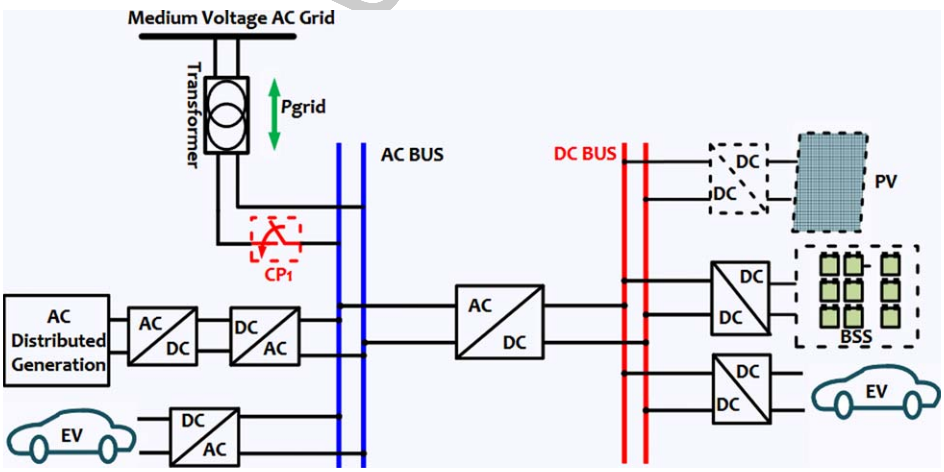

Fig. 3. Different charging station configuration of proposed method.

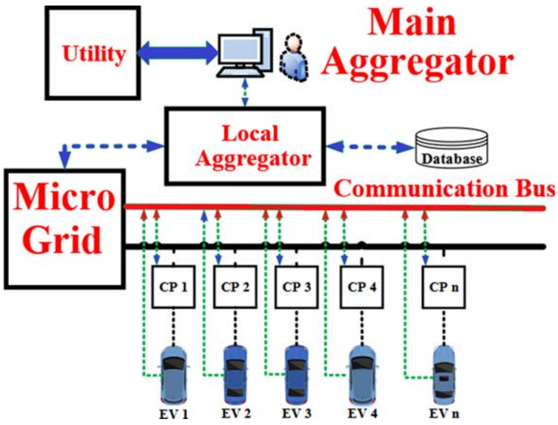

Fig. 4. Centralized distribution control architecture.

4. Adaptive hybrid swarm based optimization

A PSO and swarm based optimization algorithm was frequently used to tackle optimization problems [33]. Because of its simple way of implementation and efficiency in handling various test functions such linear or non-linear engineering functions, it's also widely utilized in real-world optimization issues including resource allocation, electrical vehicle [34], mechanical engineering [35], and a many of other tasks [36]. A proposed AHWPSO is collaborative version that includes master swarm based optimization. Which improves the characteristics of particles trusting aggressive development. Here, we include GWO's hunting behaviour into PSO. Our proposed technique differs from the algorithm given in [37–39] that we employ an adaptive time-varying EVCS and do not use the inertia weight parameter during the hunting phase. Moreover, the proposed PSO velocity update for AHGPSO used alpha position ((t)) along with wolves hunting positions ($X_1(t)$, $X_2(t)$, $X_3(t)$). The proposed formula is expressed using Equations (6).

$$V_i(t+1) = \omega(t) * V_i(t) + C1r1\ (X\alpha(t) - X_i(t)) + C2r2\ (X1(t) - X_i(t)) + C3r3\ (X2(t) - X_i(t)) + C4r4\ (X3(t) - X_i(t))\ ) \quad (6)$$

Where, the parameter values of $X_1(t)$, $X_2(t)$, and $X_3(t)$ are wolves' hunting position calculated using Equation (11). Our proposed EVCS parameter is based on [37], but instead of using the cost of the global best position. Hence, we use the average cost of alpha ((t)), beta ($X(t)$), and delta ($X\delta(t)$) position from GWO. The optimization problems of objective function as shown in Equation (7 to 9), that is express the converter duty cycle (α), EVCS losses (β), and switching angle (δ presented. Table 1 shows that

Proposed Algorithm AHWPSO

Crete model with n static objuects
Create Particle/Swarm and initialize the position randomly
Set the parameter $\boldsymbol{\omega}$, $\boldsymbol{c}_1$, $\boldsymbol{c}_2$, $\boldsymbol{c}_3$, *and* c_4
For $\boldsymbol{It} = \boldsymbol{1}$ *to* ***MaxIter*** *do*
  For $\boldsymbol{i} = \boldsymbol{1}$ *to* $\boldsymbol{N}_{pop}$ *do*
    Evaluate the cost function to find search particles α, β *and* δ.
    Store α *position as best position.*
  End For
  For $\boldsymbol{i} = \boldsymbol{1}$ *to* $\boldsymbol{N}_{pop}$ *do*
    Calculate $\boldsymbol{\omega}(\boldsymbol{t})$
    Estimate the target position X_1, X_2 *and* X_3 *based on search particles* α, β *and* δ.
    Update particle velocity
    Calculate particle new position
  End for
End for
Output the best path for the EVCS

parameters are used proposed AHWPSO algorithm. Figure 5 is illustrated the flowchart for proposed method.

$$W\alpha(t) = \frac{Avg\ (f\ \ (X_\alpha(t))}{Avg\ \ (X_i(t))} + \frac{\omega * t}{Max\ Iter.} \quad (7)$$

$$W\beta(t) = \frac{Avg\ (f\ \left(X_\beta(t)\right)}{Avg\ \ (X_i(t))} + \frac{\omega * t}{Max\ Iter.} \quad (8)$$

$$W\delta(t) = \frac{Avg\ (f\ \ (X_\delta(t))}{Avg\ \ (X_i(t))} + \frac{\omega * t}{Max\ Iter.} \quad (9)$$

5. Result and discussion

In this section describes the performance analysis of proposed method. This AHWPSO approach is well suited for EVCS. Hybrid approach is executed with MATLAB simulink site. The objective of the proposed approach is cost minimization, reduce losses, and voltage deviation. In the first EVCS and the distributed generation are located in micro grid network. In MATLAB, the electric vehicle charging system is simulated. The simulation's objective is tested the ability of AHWPSO algorithm based EVCS by an uninterrupted charging process.

Case: 1 (PV-Wind Power Development)

In this study, the hybrid renewable energy is incorporated with in this system, the load power is 1.5 kW. Therefore, to compensate the output power then the input power is increased up to 1.75 kW both PV &

Table 2
Comparison of EVCS architecture both AC/DC power

Architecture	Advantage	Disadvantage
AC bus based Charging System	• Represent a simpler concept, well-develpoped standards and technologies are available. • Reliable switching and control considering the zero crossing. • Active/reactive power management can be decoupled which simplifies the AC voltage/frequency control. • Charging unit can be individually connected to grid.	• Fast chargers with separate rectifier stage can cause undersirable harmonic effects on the power grid. • The cost of multiple converters with low rated power is greater than that of a single high-power converter, due to the large number of control stages and filters. • Renewable that are inherently DC, will require an independent DC/AC stage, consequently, the system's cost and complexity. • The power quality and stability of indicators such as bus voltage and frequency, control and operation are difficult ot find and acheive.
DC bus based Charging System	• Provides a more flexible structure, which can easily integrate RES and ESS. • Higher power density and overall efficiency, low losses, low complonent number and cost reduction. • Promotes the concept of a central charging station serving which minimize the impact of the high density EVs loads in public locations on the grid. • No issues with control nor reactive power and frequency exists	• Requires more complex protection devices because no zero cross points of the voltage exixts. Switching losses become relevant when the power range is high. • The increase in the nominal power of the central converter causes more severe requirements for the grid, in terms of harmonic component amplitude and overall harmonic distortion.

wind. Figure 6 shows the solar outcome with EVCS load profile under normal operating condition, in this graph 24 hours load output solar power is peak position. Increase the solar & wind power is regularly and energy is stored to battery unit. In case low wind and insufficient irradiation occurs automatically the battery back-up is fulfilled by the activating additional charge to EVCS. One day input power charging operation under normal weather condition and also wind conditions as shown in Fig. 7. Its display the wind outcome with EVCS load profile under normal operating condition, in this graph 24 hours load output wind power is peak position. MPP tracking the renewable power both PV and wind this curve indicate the maximum output power is delivered with short time period.

Case: 2 (DC-DC & DC-AC Converter Power Development)

In this study, an intermediate DC/DC & DC-AC converter is used in a RES to optimise the power harvested from the solar/wind profile. The interleaved converter also offers controlled voltage at the output in this scenario by using AHWPSO. To facilitate bidirectional power flow to maintain power balance in a bidirectional converters architecture is controlled with duty cycle, and switching angle values. The designed and development of battery unit is incorporated with converter unit. A rectifier/inverter conversion stage is built on the micro grid side to maintain the DC bus regulated and to facilitate bidirectional power flow between the AC/DC grid and the other components of the hybrid power sources.

Case: 3 (Distribution EVCS-DC & AC grid output)

The algorithm steps are designed to optimize the use of renewable energy while reducing grid demand. Proposed algorithm looks for an EVCS load, as well as available PV/wind power, and the battery energy condition. Depending on the SoC of the battery, the state of RES aided battery energy will offer the charging process or act as the load. Grid plays a role in mitigating the shortage for charging EV loads and storage charging unit by supplying extra power from the grid. The proposed algorithm is highly sensitive to grid peak demand periods, and in such situation, the storage energy is effectively used to either extract more energy from PV/Wind to complement in the event of a deficiency. To increase charger uses and charge EVCS in a timely manner, but an hours based result the RES may adjust the charging level based on EV demand, where the DC charger is 500 V and 43A.

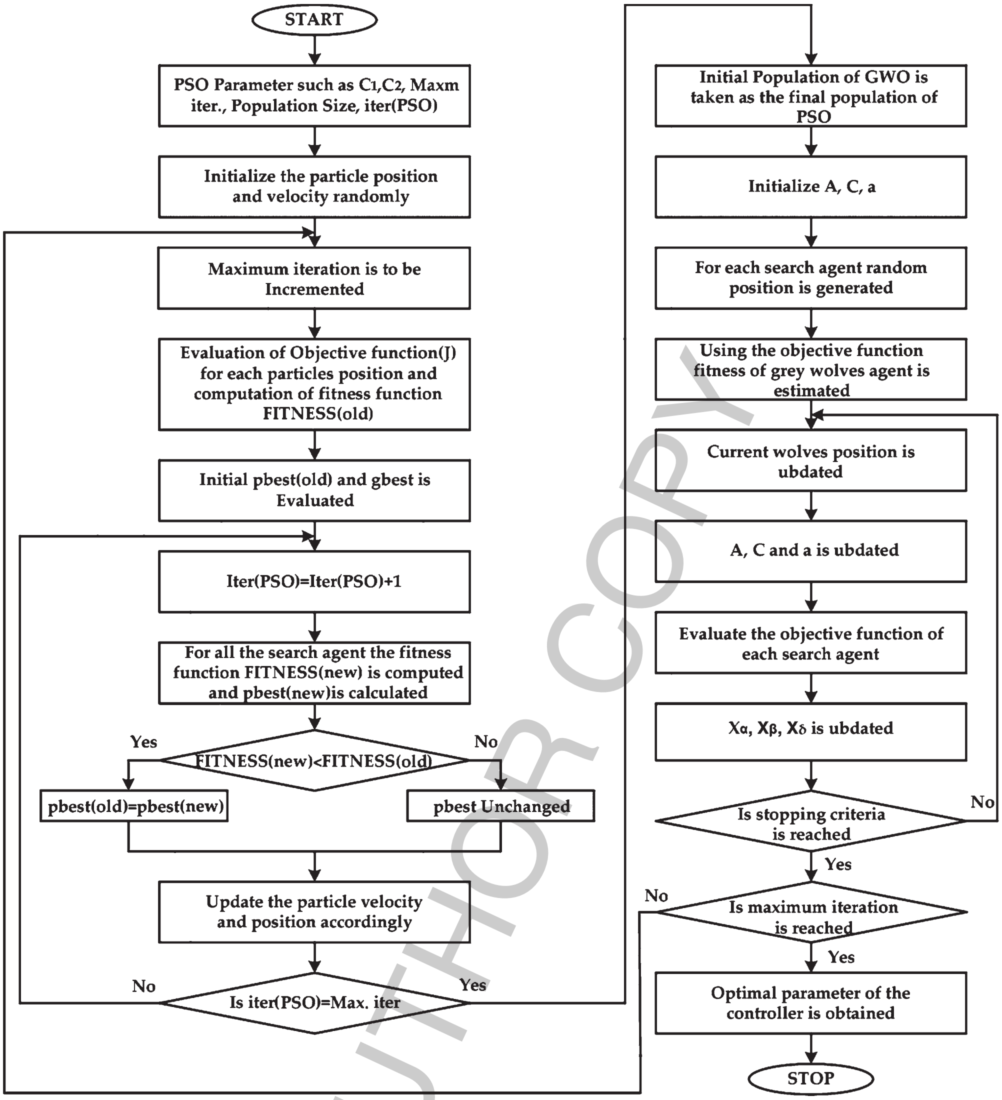

Fig. 5. Proposed AHWPSO algorithm flow chart.

The amount of power supplied PV to EV and Wind to EV should be varied. The EVCS output voltage and current as shown in Fig. 8.

Step: 1 (PV/wind to EV) solar/wind power is presented in the proposed system. Therefore, PV/wind power to EV power demand equations are derived in 10 &11.

$$PV\ to\ EV = EV\ demand * \Delta t \tag{10}$$

$$Wind\ to\ EV = EV\ demand * \Delta t \tag{11}$$

Step: 2 (PV/wind to EV) solar/wind power is not partially available or RES power is less in the proposed system. Therefore, PV/wind power to EV power equations are derived in 12 &13.

$$PV\ to\ EV = PV\ power * \Delta t \tag{12}$$

$$Wind\ to\ EV = Wind\ power * \Delta t \tag{13}$$

Step: 3 (Battery storage to EV). If the RES is unable to individually satisfy the EVCS demand while also overloading the grid that instantaneous of time, the step-3 is activated. Then the energy delivered will be modified depending on two alternative circumstances, the power sharing SoC battery outcome as shown in Fig. 8.

Table 3
Proposed AHWPSO algorithm parameters

Description	Parameters	Values
GWO [37]	Total number of iteration	100
	Population size	90
	Number of particles	60
	Archive size	90
	Member selection/ Leader selection pressure	2/4
	α grid inflation parameter	0.2
	Number of grid per dimension	20
PSO [33]	Total number of iteration	100
	Cognitive factor C_1	1.5
	Social factor C_2	1.5
	Inertia weight (w_{min} - w_{max})	0.5–2.0
	Number of particles	60
	Population size	100
Proposed AHWPSO	Inertia weight W	0.9
	Local weights C1, C2, C3, and C4	0.2,0.5,0.8, & 2.0
	Population size	200
	Number of iteration	150
	Number of particles	60
	Initial duty cycle	0.5
	Optimum switching angle	0.75

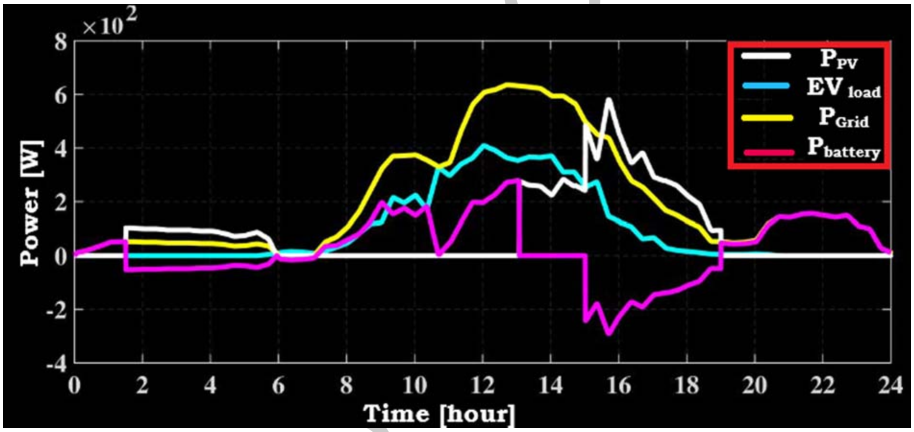

Fig. 6. Daily PV power Load curve.

Table 3 is Proposed AHWPSO algorithm parameters using EV charging station.

The charging system is under operating in 3 category:

- No load – EVCS demand is zero, then RES power is presented.
- Under load – EVCS demand is less than or equal to RES power.
- Over load – EVCS demand is higher than RES power.

The smart grid output voltage and inverter output shown in Fig. 9. Solar/wind power is lower than the storage power, hence battery demand to EV power equations are derived in (14&15).

$$Battery\ to\ EV = (Battery\ demand - PV\ power) * \Delta t \quad (14)$$

$$Battery\ to\ EV = (Battery\ demand - Wind\ power) * \Delta t \quad (15)$$

6. Conclusion

RES and electric cars are crucial components to reducing CO_2 emissions and fossil fuel usage. Despite the fact that electric vehicles are more cost effective and ecologically benign than gasoline vehicles, and greater then penetration of electric vehicles

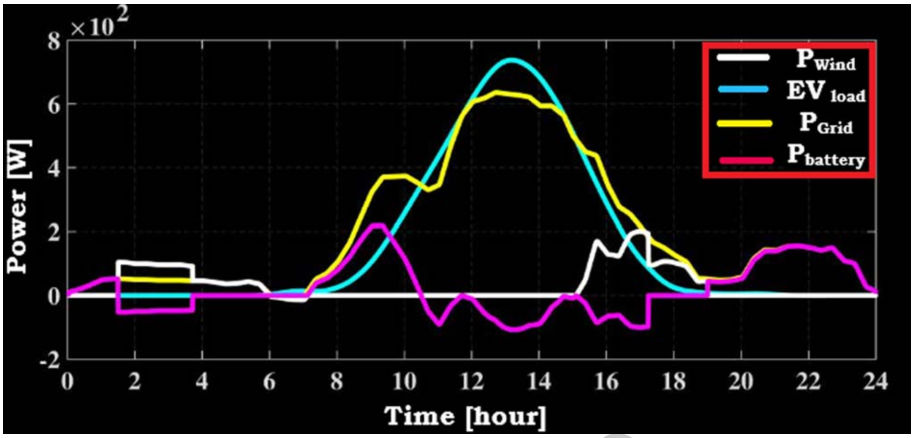

Fig. 7. Daily Wind power Load curve.

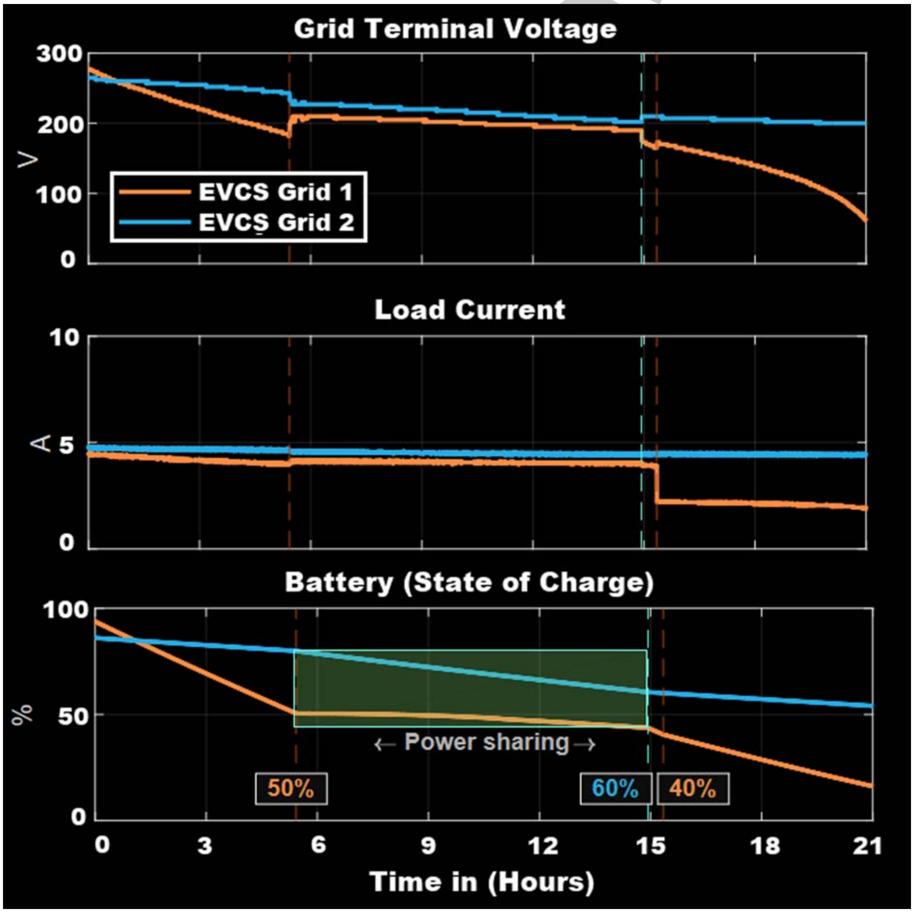

Fig. 8. Proposed EVCS output voltage, current and battery status.

is hampered for a variety of reasons. The most visible of these factors are the charging scheduling of electric cars and the efficient design of dedicated charging facilities. In this context, creating a specialised charging station can reduces the cost on the main grid, while allowing for more effective load scheduling for electric vehicles. Proposed AHW-PSO algorithm is well suited for EVCS, because the

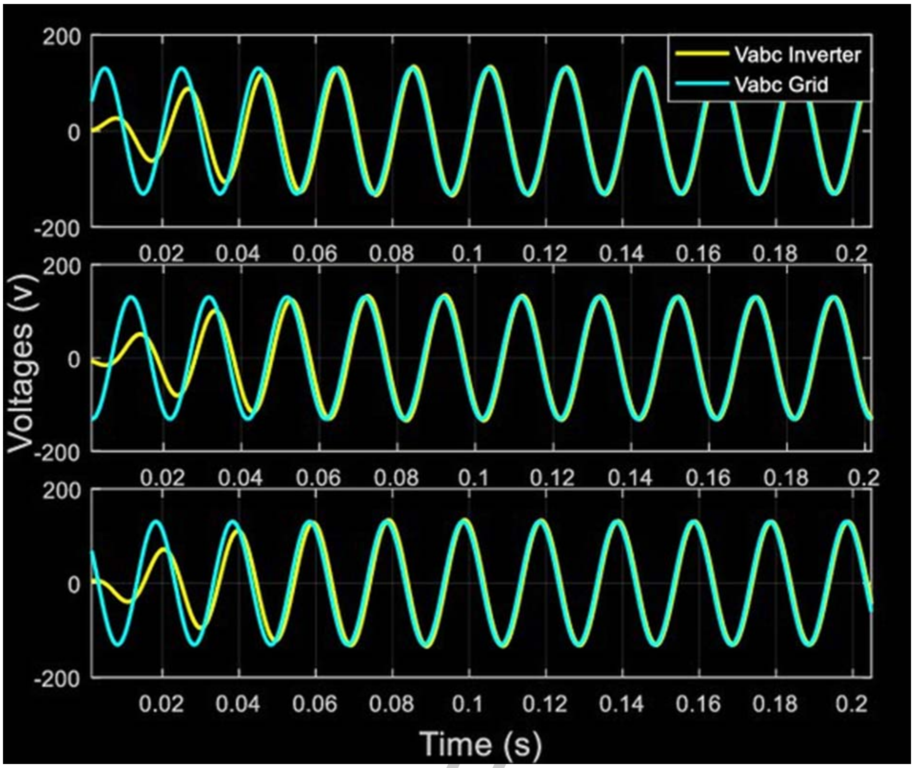

Fig. 9. Proposed grid output voltage.

minimization loss, and improved efficiency of the grid output.

A dedicated renewable assisted charging station is suggested and simulated. Therefore, it verified in this study under various operating condition and load profiles. The wind/PV, battery storage unit, and EV loads are all connected by a single DC bus. Furthermore, a converter stage connects the main grid to the common DC bus. The overall decrease in power conversion stages is one of the advantages of adopting a common DC bus. Interleave converters are used independently for RES, battery unit, and EVs loads in the context of power conversion to improve conversion efficiency while delivering a dependable and consistent power supply. In future study on RES to grid connected EV charging and discharging management can contribute in discovering a balance between vehicle owner requirements and power grid stability. More homework is needed due to the rising penetration of RES and EVs in the power market. On vehicle owners' responses to grid operator requirements should be conducted. This is standard research that measures both produced power costs, and charge costs should be investigated.

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