Intelligent Control Technique in Electric Vehicles – part 2

control system, charging stations,
integration with the smart grid

Nataša Popović, PhD

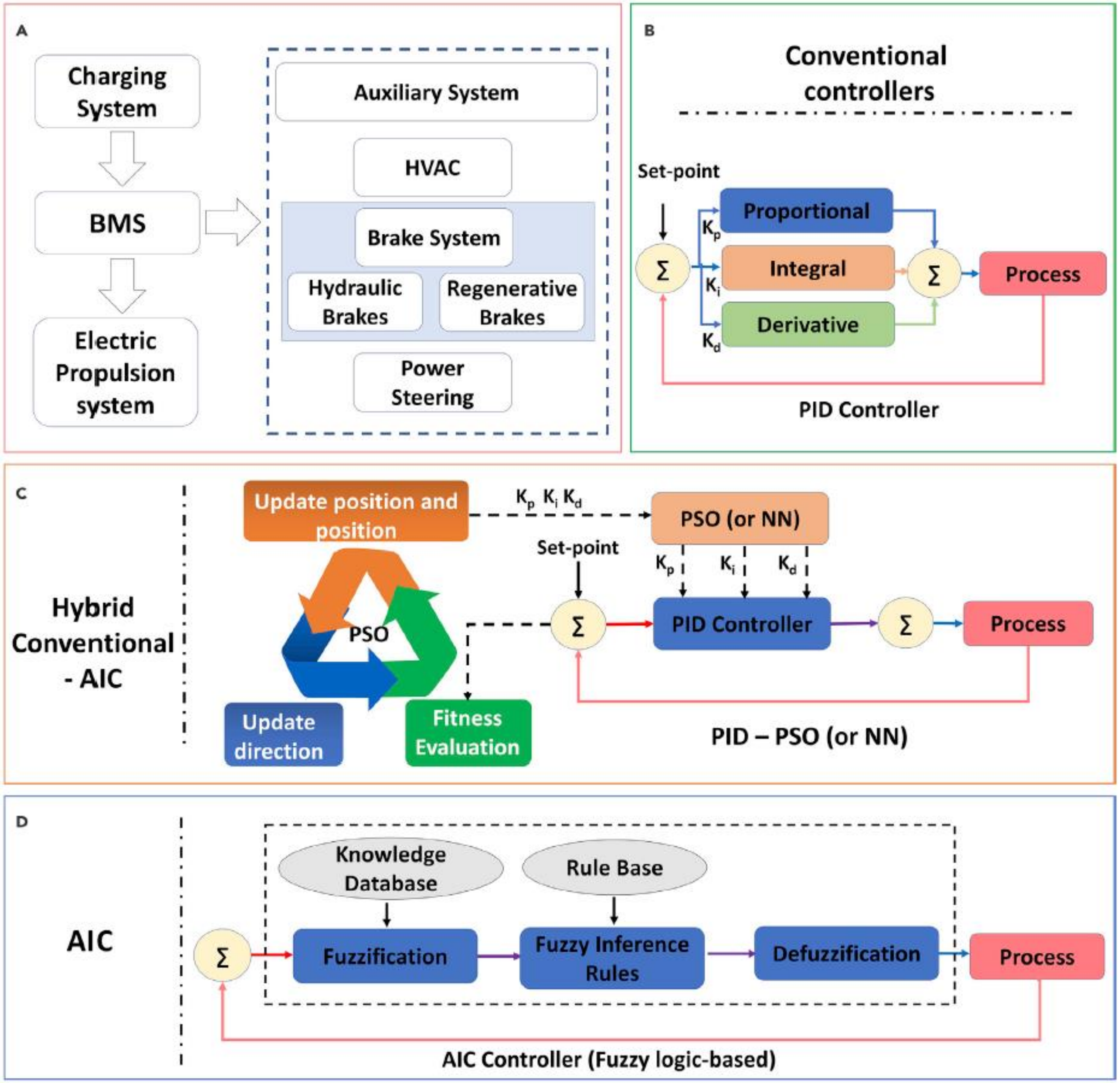
1. AI in EV control system

- ✓ Optimal EV control-system use ensures reduction in energy consumption of EV hardware including power steering, regenerative braking, and internal environment hardware controls such as HVAC while maximizing vehicle speed.
- ✓ Artificially intelligent controls (AICs), involving AI techniques such as fuzzy logic, NN, and evolutionary algorithms, can be either used as a substitute for or in conjunction with conventional industrial controllers, such as PID controllers.
- ✓ Among current optimization strategies for EV control systems, AIC, is a smart choice for EV control-system design and optimization to improve the energy efficiency.

1. AI in EV control system

- ✓ CI algorithms for particle swarm optimization (PSO) and ant colony optimization (ACO) applications:
  - to tune the critical parameters of PID controller to reduce the process's steady-state error and overshooting,
  - to aid in reducing the assisted current drawn by the electric power-assisted steering (EPAS).
- ✓ Fuzzy-logic controller (FLC) and NN:
  - ✓ in HVAC systems because they can effectively handle user comfort while reducing energy consumption,
  - ✓ In braking (e.g., braking pedal displacement), battery (e.g., SOC and temperature), and vehicular speed can be used as FLC inputs to optimize the braking allocation,
  - ✓ the smart grid.

1. AI in EV control system

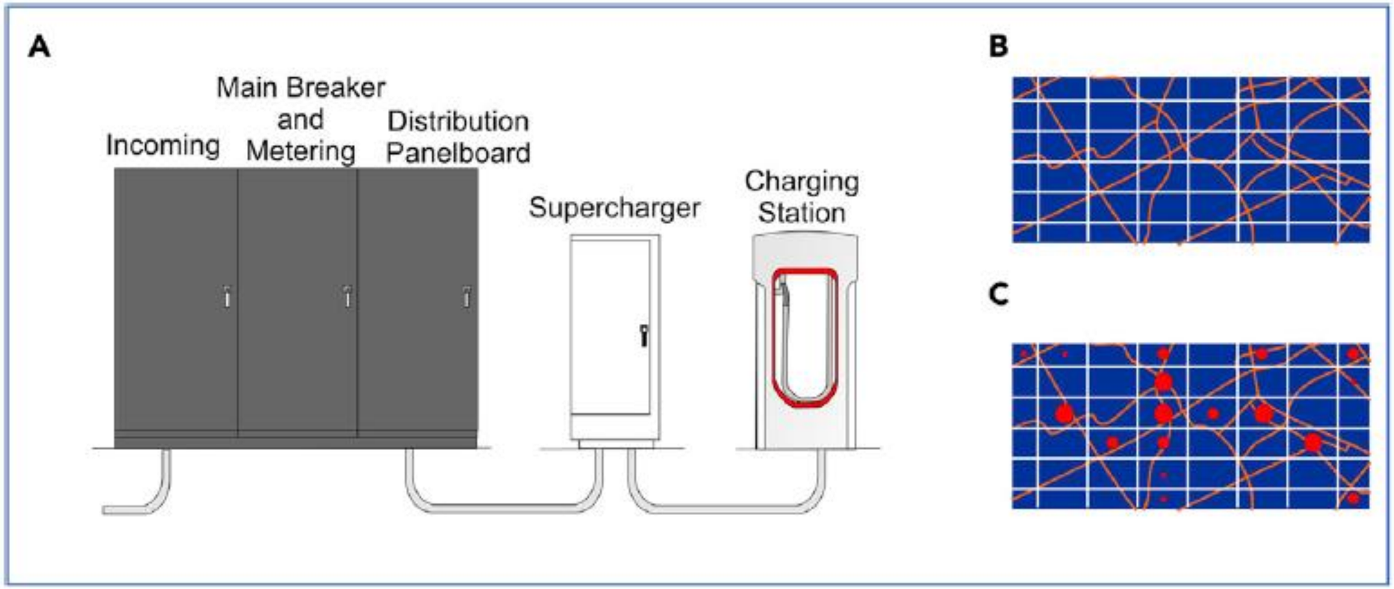


2. AI in EV charging stations (EVCS)

- ✓ Optimal placement of EVCS depends on several factors, such as the local charging demand, construction feasibility, road network and other infrastructure, operating economy, and power-grid security..
- ✓ Optimal placement of EVCSs is generally formulated as a multiple objective optimization (MOOP) function with objectives comprising minimization of costs, maximization of net present value (NPV), or preference to unpopulated areas.
- ✓ ML is used for preparation of data or models for these MOOPs,129,126,137 and CI, including swarm intelligence (e.g., PSO) and evolutionary algorithms (e.g., GA) can be used for solving these MOOPs.
- ✓ EVCS placement without MOOP has been solved by using supervised ML algorithms such as K-means clustering,Bayesian networks, and NN.
- ✓ To determine EVCS placement and sizing agent-based models (ABM) can be used where different agents (such as EV owners,n EV drivers, and EVCSs) are assigned different attributes and interact with each other in a model environment within a geographical location

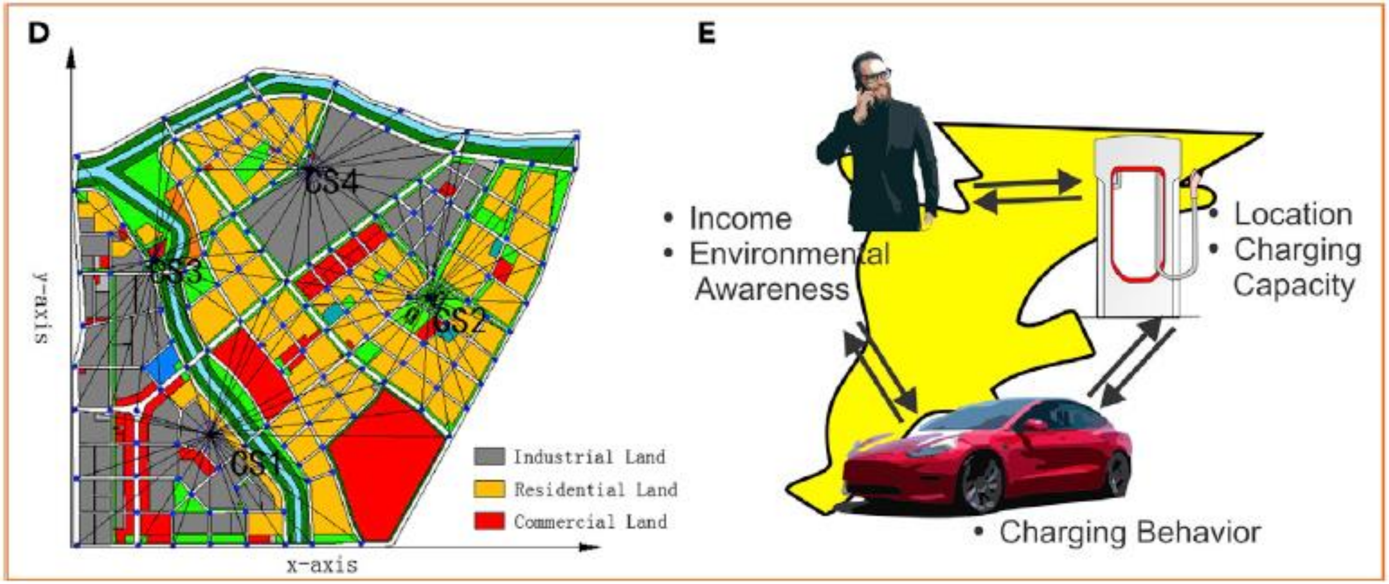
2. AI in EV charging stations (EVCS)

- ✓ (A) Tesla superchargers consisting of distribution panelboard, metering, and incoming power source.
- ✓ (B and C) Clustering of spatial map based on traffic density and EV driving distance. For trafficdensity distribution, the traffic data of road segments within a predetermined grid are aggregated and overlaid on the corresponding grid. As shown, the traffic density is pictorially represented by the radius of the red circle. For driving-distance clustering, the regions on the map are clustered based on the location of EV and its destination points.



2. AI in EV charging stations (EVCS)

- ✓ (D) Objectives of EVCS are modeled by using as a MOOP problem, which is solved by using CI algorithms (PSO) PSO was used to solve for MOOP, which considers land-cost and distribution investments; meanwhile running cost was considered as the restraint. Solutions of PSO lead to Pareto solutions of optimal EVCS placement.
- ✓ (E) Agent-based modeling for EVCS optimal location. In this example, the agents (EV owners, EV drivers, and EVCSs) are placed in a geographical environment and their attributes (mentioned in the figure) are modeled. The two-sided arrows represent the interactions between the agents.



2. AI in energy scheduling and congestion management

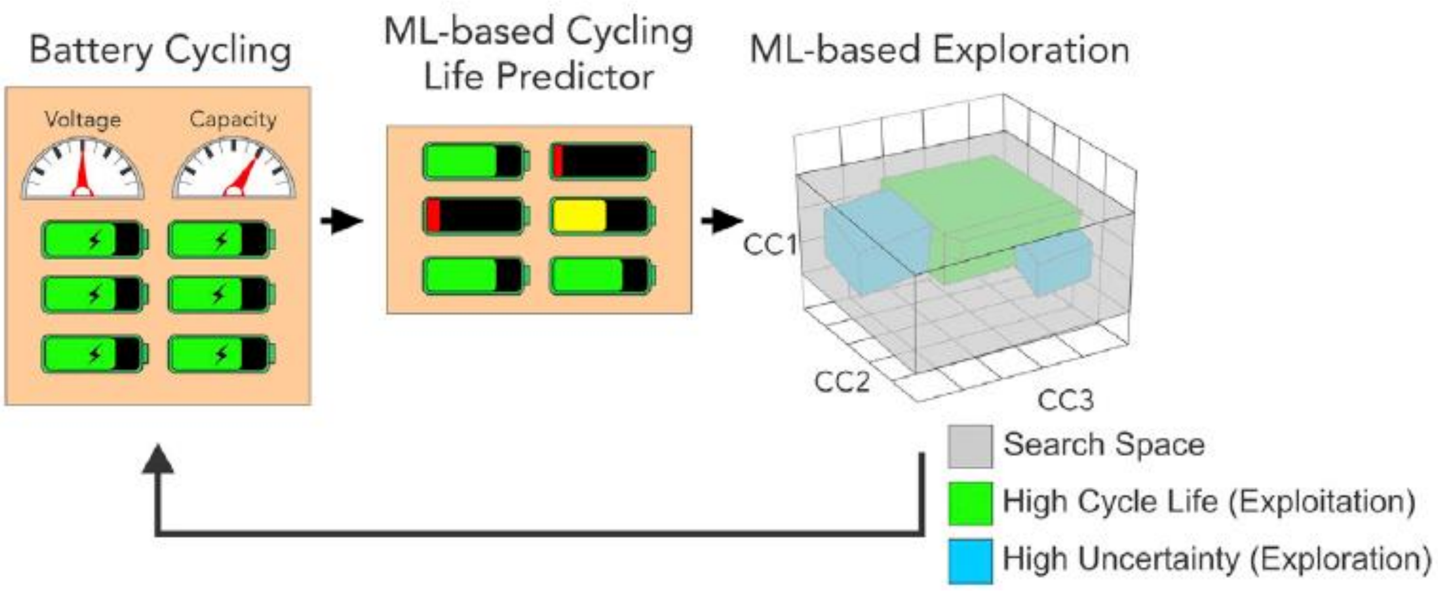
- ✓ AI-based routing algorithms can be used to further improve the efficient use of existing infrastructure such as EVCSs via energy scheduling and congestion management.
- ✓ ML algorithms, including linear regression and NN can be used to predict the charging behaviors of EV consumers and estimate the energy demand.
- ✓ ML methodologies are applied to any specific geographical location for accurate EVCS demand and charging predictions.
- ✓ ML for current determination for the fast charging of lithium-ion batteries while setting the number and time of charging stages.

2. AI in energy scheduling and congestion management

- ✓ RL for congestion management: The map of three EVCS is mapped into a grid where each EV starts from the same starting point and the relative distance of EV to EVCS is maintained. Furthermore, the traffic density of the road segment is mapped onto the individual grid. The RL algorithm optimizes the congestion policy to minimize the total EVCS waiting time.

2. AI in energy scheduling and congestion management

✓ Bayesian-based ML model for fast-charging protocol: In this iterative ML-based charging protocol, the outcome of the battery is determined by using a predetermined ML algorithm. Based on this early outcome prediction, the Bayesian optimization determines the next charging outcomes for successive cycles in the four-stage MCC charging protocol. The Bayesian-based ML algorithm, along with the ML-based early-life predictor, finds the charging protocol, i.e., the C-rates, for the first three cycles



3. AI in the integration of EV with the smart grid

- ✓ Smart grids, in comparison with the traditional electric power distribution systems, allow for two-way energy flow, secure dynamic optimization of energy flow operations— such as determining the pricing of charging an EV based on the supply and demand of electricity—and smoother integration of renewable-energy production and storage.
- ✓ The direction of energy flow from the grid to EVs is referred to as grid-to-vehicle (G2V), in the case of EV charging, and vehicle-to-grid (V2G) in opposite energy flow.
- ✓ V2G and G2V also face several technical, economic, legal, and social challenges, which include social resistance to V2G, energy distribution complications, hardware barriers, and high investment cost.
- ✓ One typical challenge is the scheduling and distribution of the smart grid with EV.
- ✓ AI algorithms can regulate the energy scheduling and optimization problems resulting from the complex two-way interaction between the EV aggregates and renewable-energy generation systems.
- ✓ AI can be also instrumental in ensuring smooth powerdistribution considering renewable-energy generations' intermittency

3. AI in the integration of EV with the smart grid

Optimization of power generation and distribution

- ✓ Power generation and distribution are restrained by meeting the load demand and supply, power-generation limits, voltage bounds, and power line thermal capacity.
- ✓ To optimize power generation and distribution both CI and ML have been investigated and applied.
- ✓ As for restraints, CI, the restraints can be first formulated as MOOP and further solved by evolutionary computing algorithms.
- ✓ MOOP can be solved by using an artificial fish swarm algorithm (AFSA) and PSO.
- ✓ MOOP can be formulated to minimize system power fluctuation and battery degradation, in which the battery lifetime model is based on a DL algorithm, specifically LSTM.

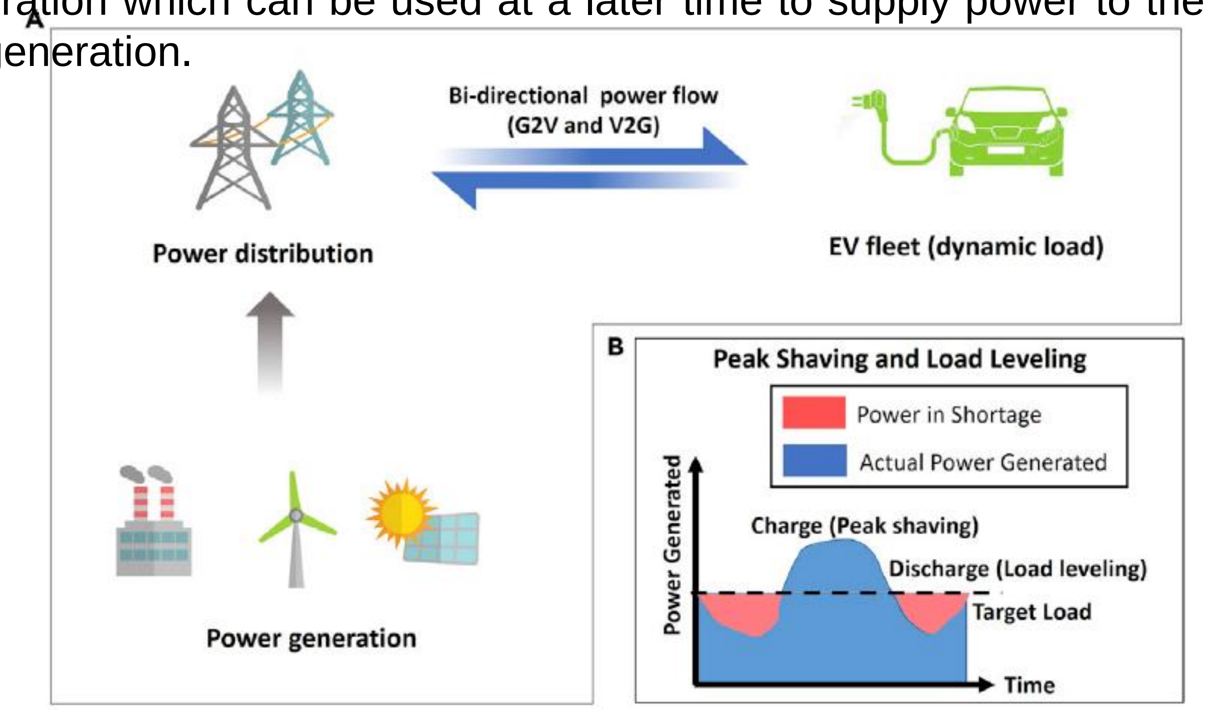
3. AI in the integration of EV with the smart grid

Optimization of renewable energy relevant systems

- ✓ Similar energy management and optimization approaches can be applied to systems with renewable energy generation systems, such as solar and wind power plants.
- ✓ In the integration of V2G with the power-generation grid with renewable-energy sources PSO is used to solve for a MOOP to minimize operation cost and maximize EV owners’ profits.
- ✓ Additionally, a MOOP sold by PSO to minimize the power grid operators and EV users’ cost, global CO2 emissions, and wind curtailment when coordinating EV charging and discharging activities with the power grid of thermal plants and wind farms.
- ✓ To minimize the high variations in wind-energy generation, GA and Monte Carlo simulations are used to coordinate the charging and discharging behavior of EV fleets, based on their daily driving habits.

3. AI in the integration of EV with the smart grid

- ✓ (A) Bidirectional energy flow between smart grid and EV. Grid-to-vehicle (G2V) and vehicle-to-grid (V2G) technologies allow for bidirectional flow of power between the EV and the grid. EV cab utilizes the power from the grid when charging its batteries. Moreover, when EV is not being used and has excess power, it can transfer that power to the grid.Moreover, this bidirectional power flow can be integrated with the renewable-power generation systems to ensure sufficient power is available in the grid.
- ✓ (B) Peak shaving and load leveling. Batteries in the EV can be used as energy storage to ensure target load is achieved in the grid. EV batteries can be charged at times of high power generation which can be used at a later time to supply power to the grid at times of low power generation.



3. AI in the c

- (C) Load regulation. The load profile can be regulated up and down to ensure that the same loading is achieved. The EV can be considered as a dynamic load when it is charging.When the fixed load is increased, Ev charging can be reduced (by increasing the power cost, for example) as in the case of regulation up. In the opposite case of reduced fixed load, EV charging can be encouraged.
- (D) Spinning reserve. In case of power outrage, addition power (spinning reserve) can be employed to compensate. The dynamic load, which includes EV charging, can be reduced, which in turn reduces the overall load.