Ministry of Industry and Trade

Hợp tác Đức
DEUTSCHE ZUSAMMENARBEIT

Implemented by giz

ERAV

FUTURE LAB 2021

V2G Application: EV Charging Management in PV Integrated Distribution Grid Regarding DSM Approach

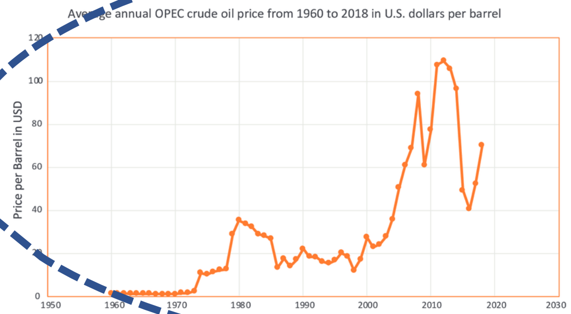
Presenter: Nguyen Duc Tuyen, Ph.D

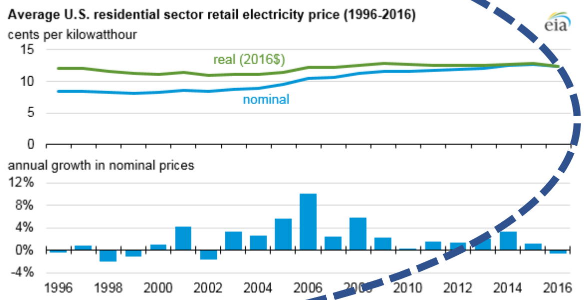
TABLE OF CONTENT

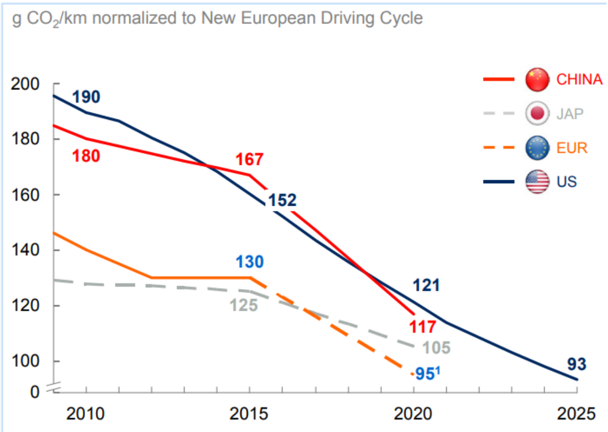
Toward 100% Renewable Energy 100RELAB

MOTIVATION FOR EV

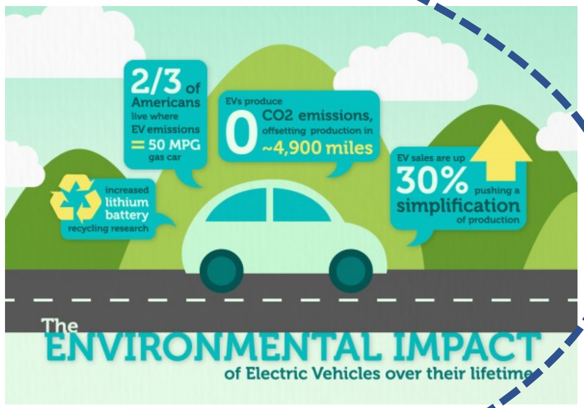
- ❑ High fluctuated oil prices, stable electricity prices
- ❑ Energy independence and energy security
- ❑ Environmental benefits







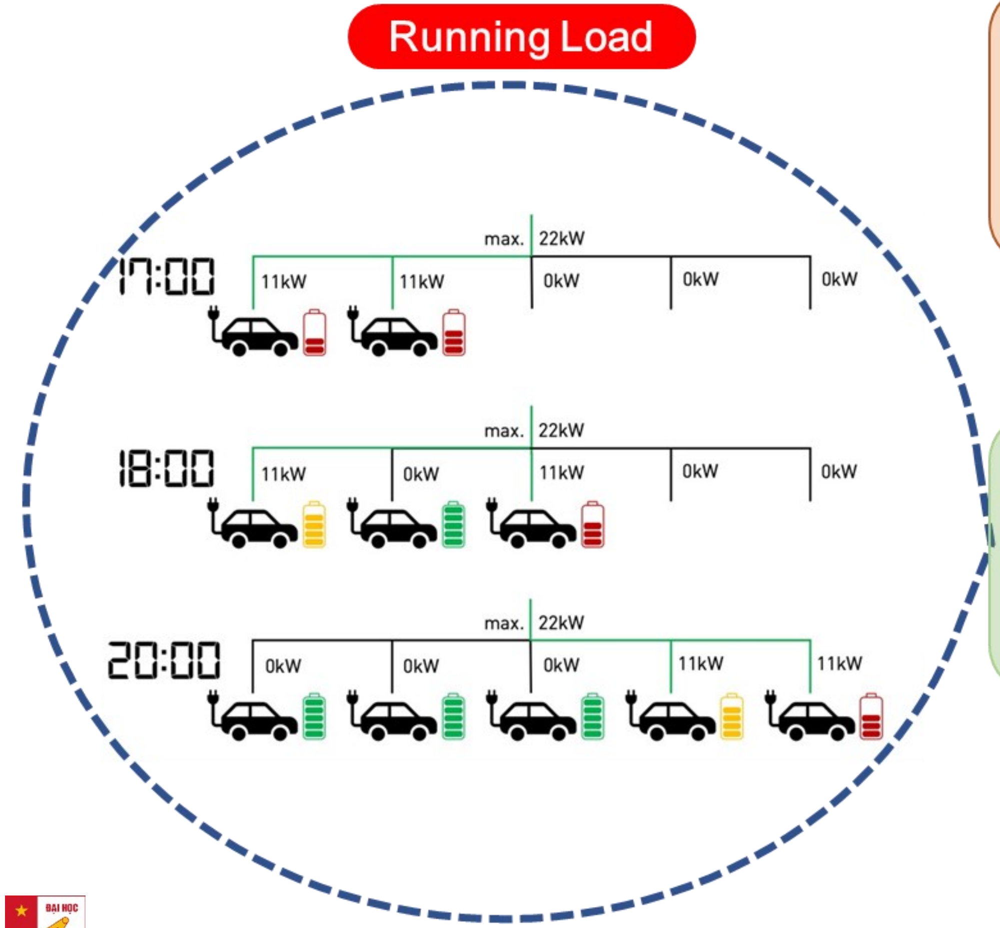
CO2 reduction targets of some countries

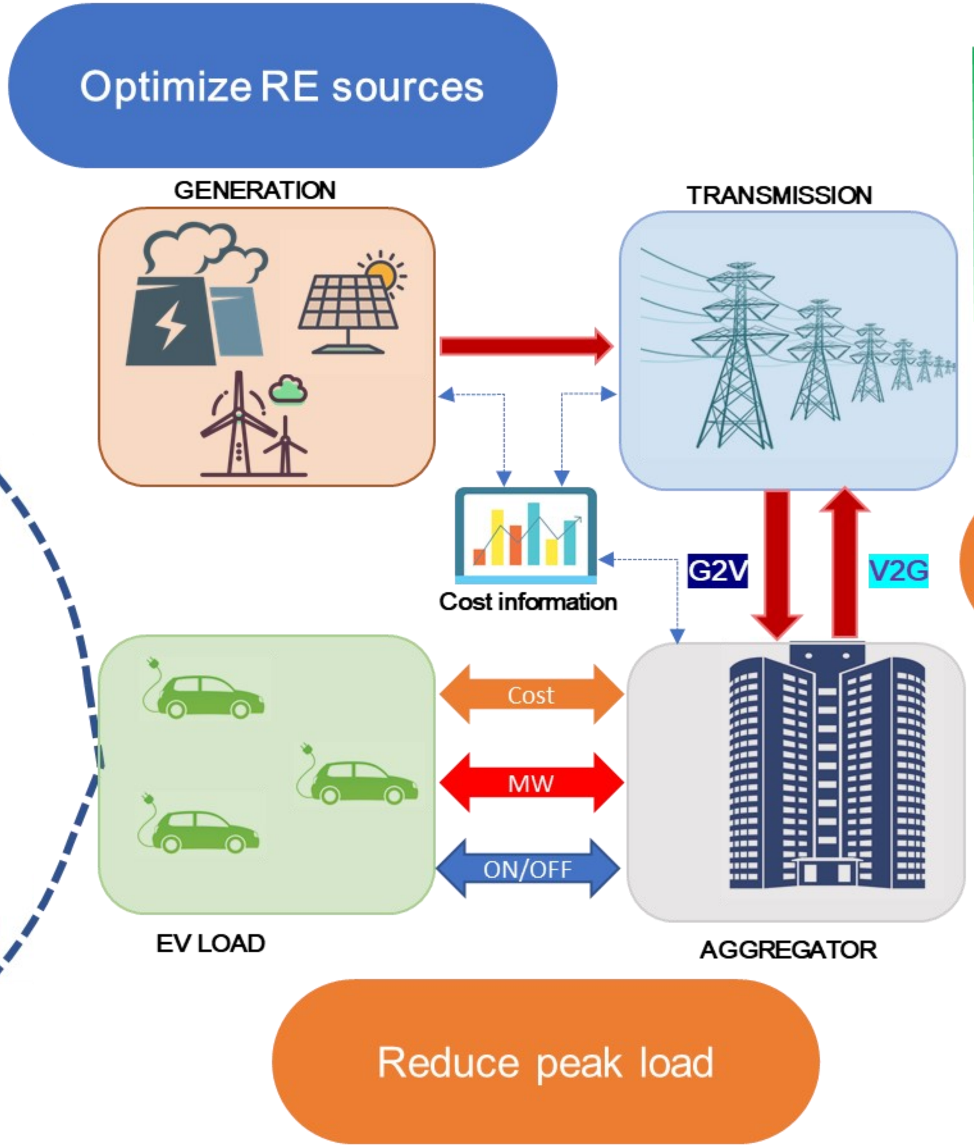


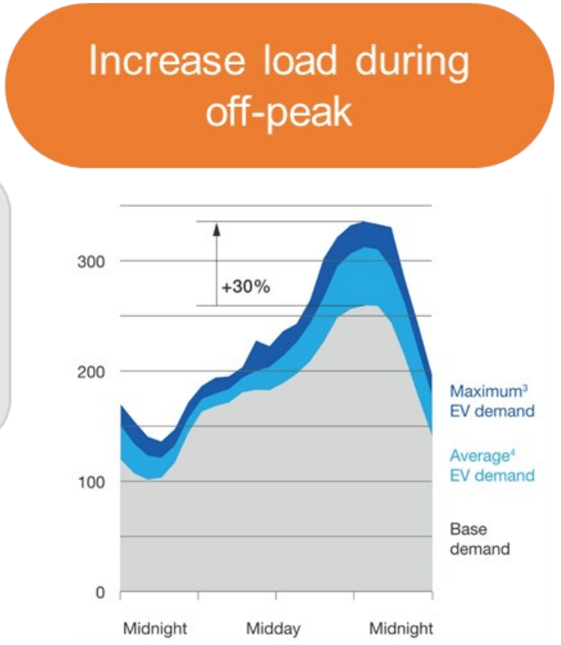
EV AFFECTS VARIOUS ASPECTS OF POWER SYSTEM

QUESTIONS

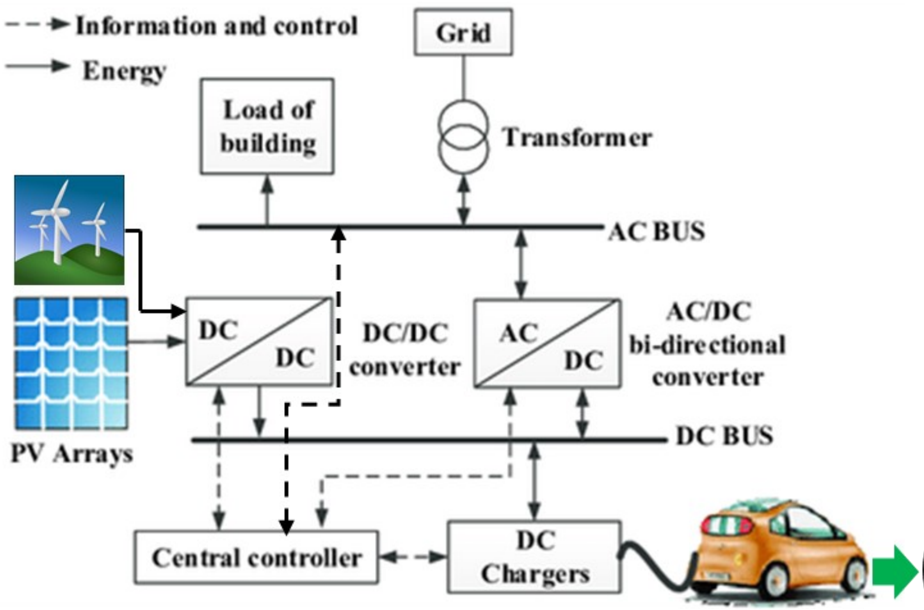
1. What is V2G?
2. Why should you care about V2G?
3. How does V2G work?
4. The benefits and drawbacks of V2G
5. How will V2G become mainstream?

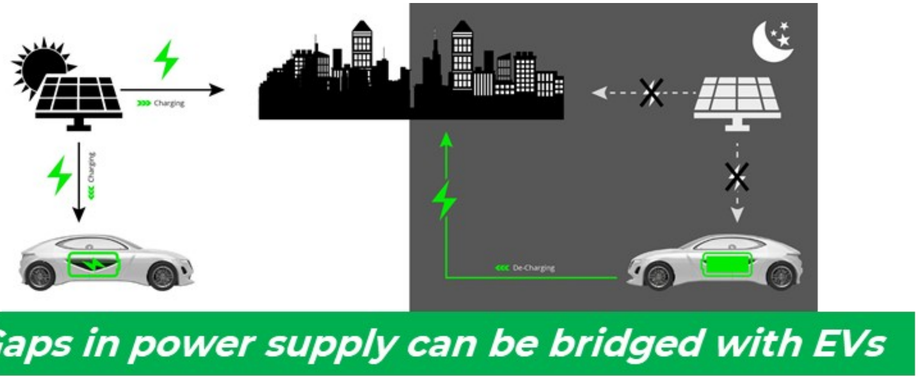






OPTIMIZE RENEWABLE ENERGY SOURCE





Electric Vehicles Type

1. Battery Electric Vehicle (BEV)
2. Hybrid Electric Vehicles (HEV)
3. Plug-in Hybrid Electric Vehicles (PHEV)
4. Fuel Cell Electric Vehicles (FCEVs)

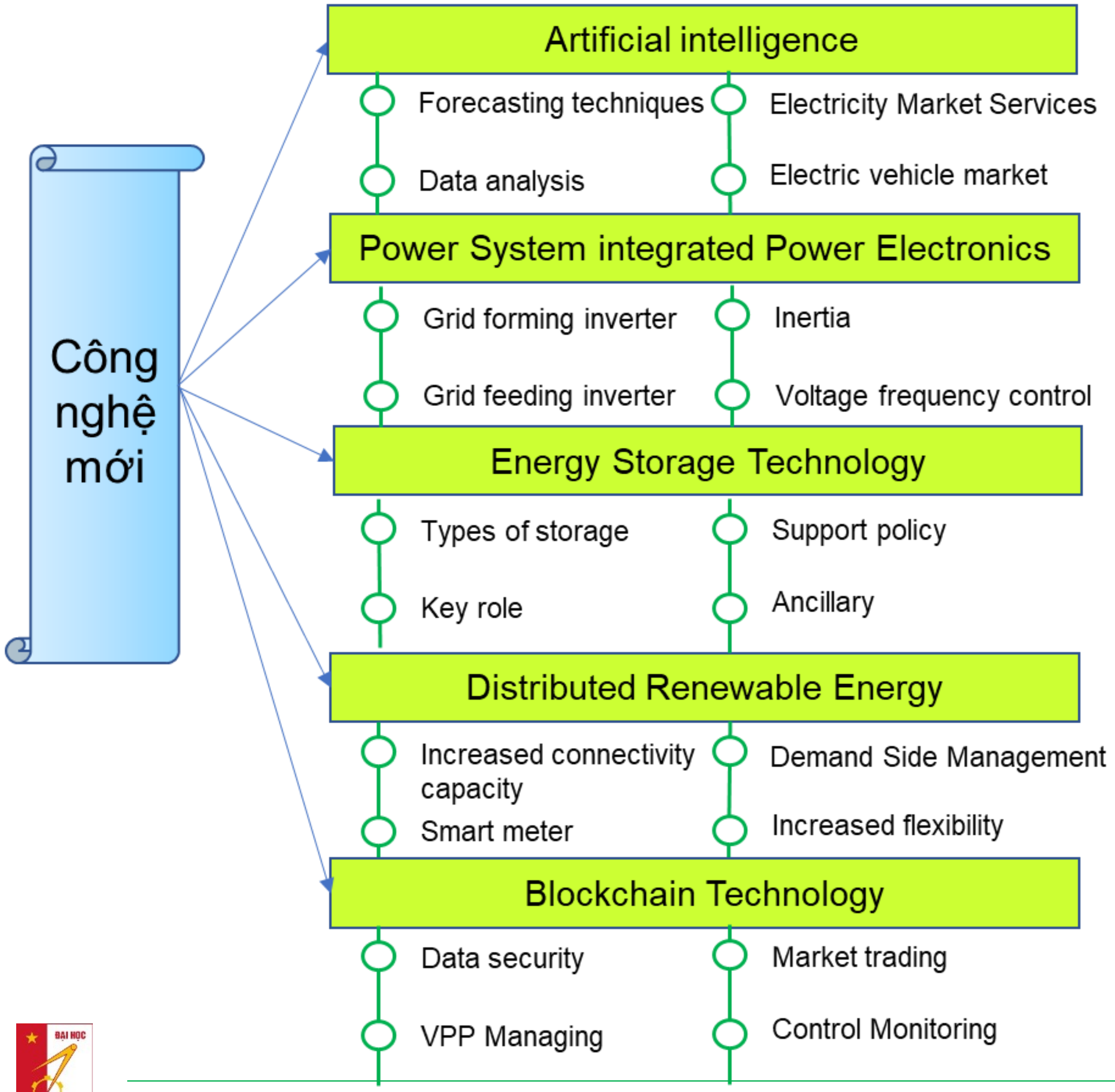
CHARGING STATION TYPE

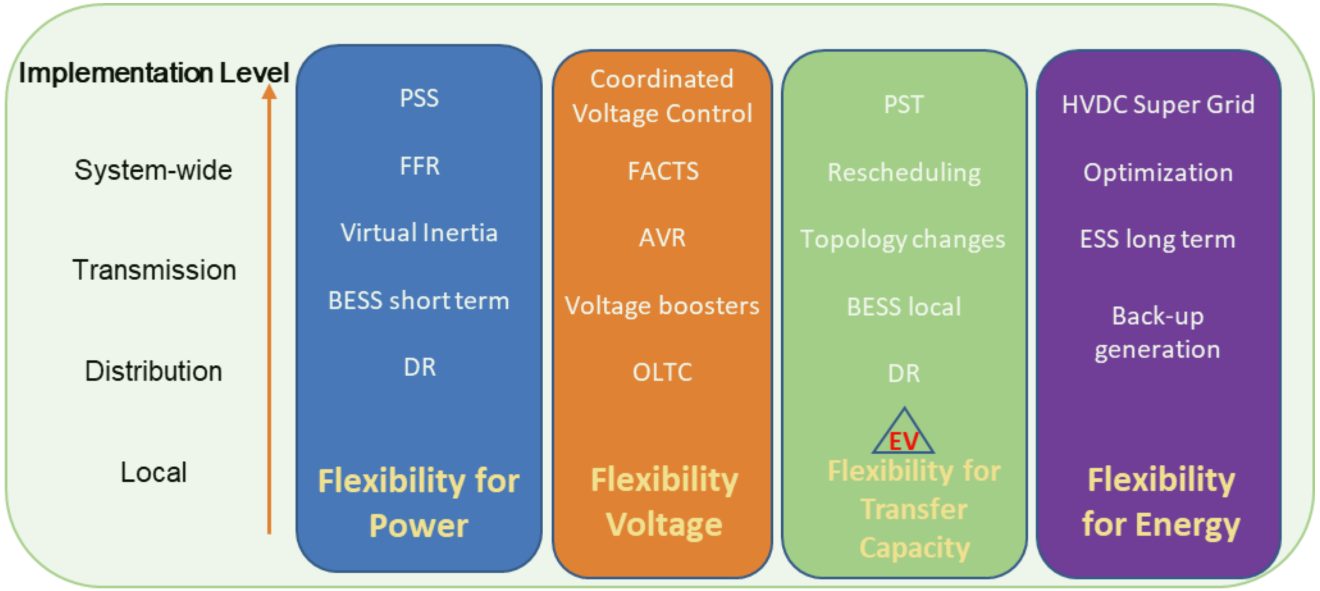
Wall box
AC < 22kW
8 – 10 hours

Public slow
AC/DC < 22 – 50kW
2 – 3 hours

Public fast
50 – 350kW
<1 hours

ELECTRIC VEHICLES - THE FLEXIBILITY OF THE MODERN GRID





- Conventional grid is not designed with the participation of EV+RE
- The purpose of EVs is transportation, but most of the time (95%) the EVs park
- Fundamentally, RE is inflexible, EVs are highly flexible
- Flexibility of EVs is demonstrated in the ability to charge/discharge at different times within the rated capacity limit $E = \int_{t_1}^{t_2} p(t)dt$

EV INTEGRATED GRID ISSUES

GOODMOTIVE

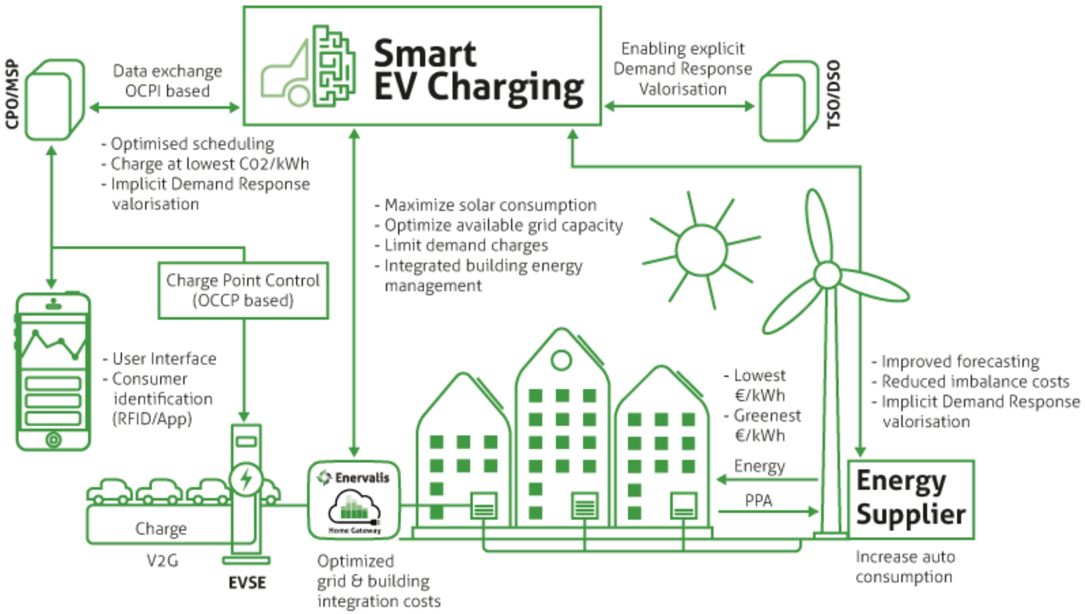
Pros

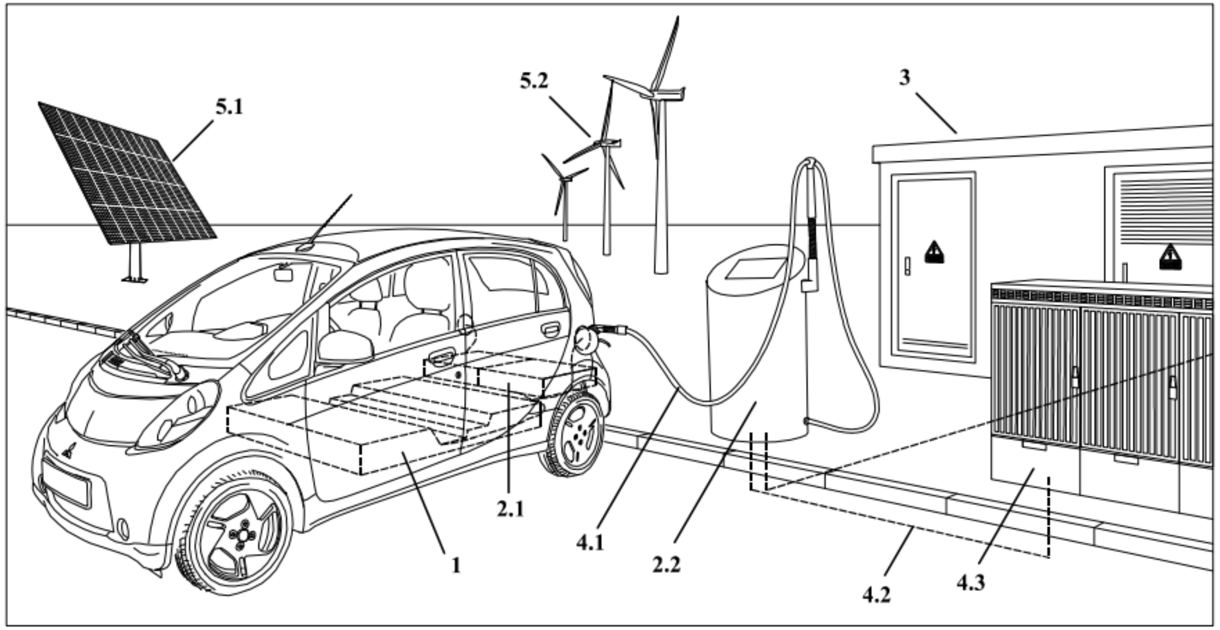
- Change the load curve
- Grid congestion management
- Avoid distribution grid overload
- Avoid redundancy of RE sources
- Ancillary Services
- Frequency voltage control
- “Behind the metter” services

Cons

- Power outages, voltage sags & short-term overvoltage, long-term overvoltage, harmonies, voltage pulses, frequency fluctuations, …
- Lack of control and unreasonable coordination at charging time with load graph will increase power loss, increase voltage deviation and power quality issues
- The share of RE is still low, if EVs are used by fossil sources, the emissions reduction are not high.

SMART (DIS)CHARGING ENHANCE V2G





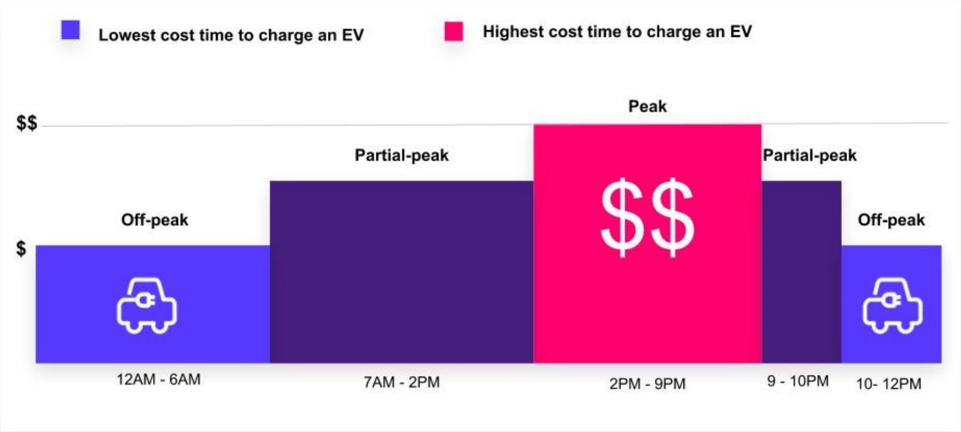
- ❖ Decide when and how EV charging occurs
- ❖ Collect EV-specific meter data
- ❖ Apply specific rates for EV charging
- ❖ Implement demand response (DR) programs
- ❖ Engage consumers with information on EV charging status and bill impacts
- ❖ Collect data for greenhouse gas credits

- ❖ 1. Battery System and Charging Management
- ❖ 2.1 On-board Charger, 2.2 Off-board Charger
- ❖ 3. Power quality at power grid connection point
- ❖ 4.1 Communication between vehicle and charging station, 4.2 Communication between charging station and central system, 4.3 Communication grid connection point
- ❖ 5.1 Solar Power, 5.2 Wind Power

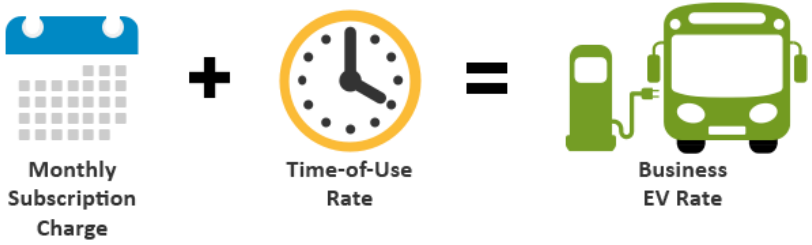
ELECTRICITY PRICING BUSINESS MODELS FOR EV CHARGING STATIONS

EFFECT OF ELECTRICITY PRICING/TARIFFS

"TIME-OF-USE (TOU)" tariffs



"DYNAMIC" tariffs



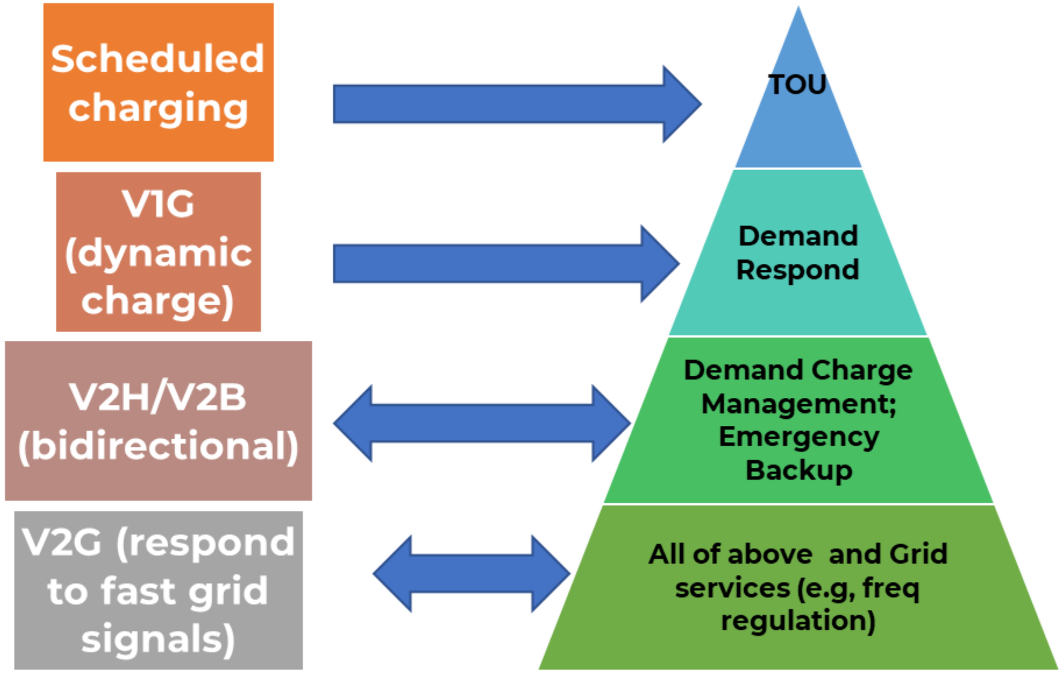
(i) Real-time prices (RTP)

(ii) Critical peak prices (CPP)

(iii) Peak time rebates

INTEGRATED FUNCTIONS FOR V2G

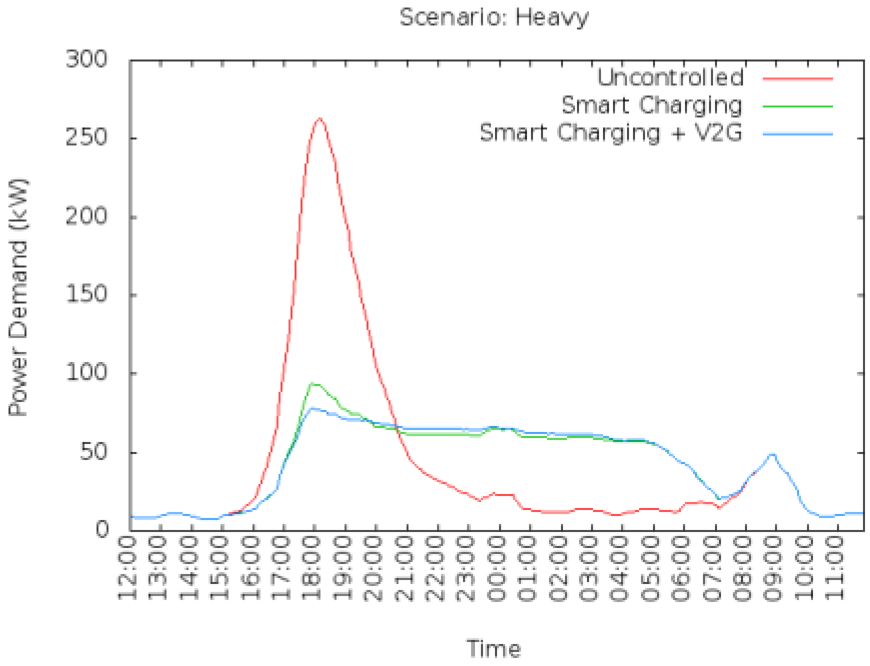
- Robust, reliable, and secure connectivity (HAN, NAN)
- Integration of EV charging infrastructure into demand side management (DSM) system
- Provision of distributed intelligence
- Provision of a separate meter at the EVSE integrated into AMI
- Integration of EV charging infrastructure into DR system
- Integration of EV charging infrastructure into distributed automation (DA) system
- Coordination with renewable energy-based generation



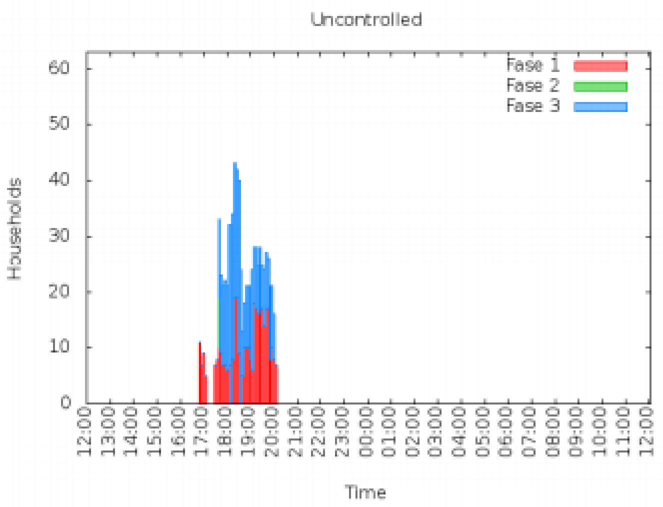
All levels of V2G (Source: Nuvve)

CASE STUDY 1:
V2G: OPTIMIZE RESIDENTIAL ENERGY CONSUMPTION WITH EV (DIS)CHARGING

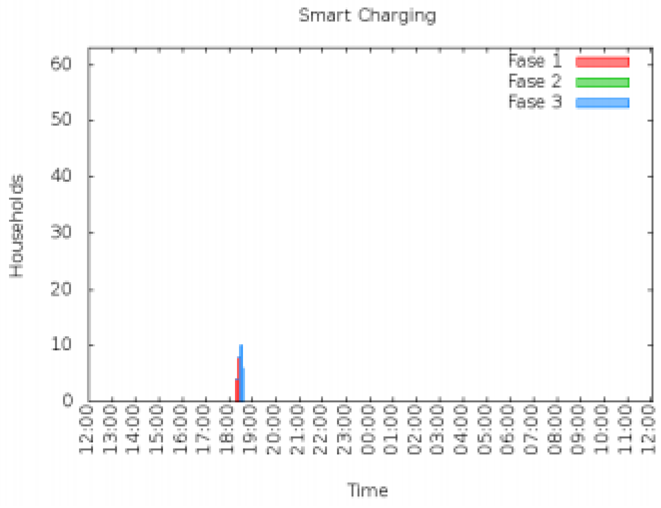
Management of the flexibility provided by EVs stored energy



Demand at level of distribution transformer, V2G reduces evening peak load



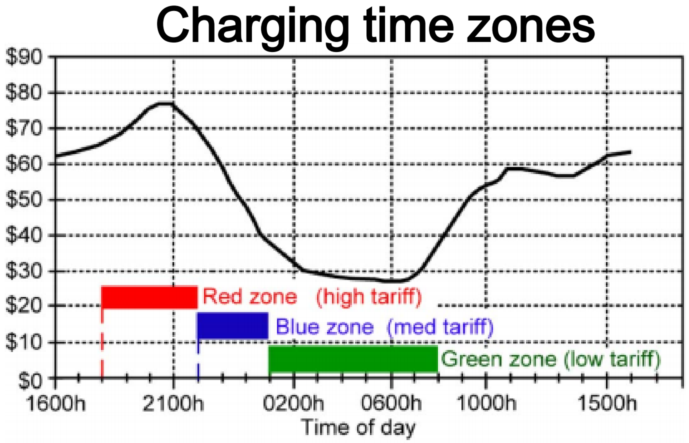
Number of households where voltage deviations larger than 10% are observed for the uncontrolled charging case.

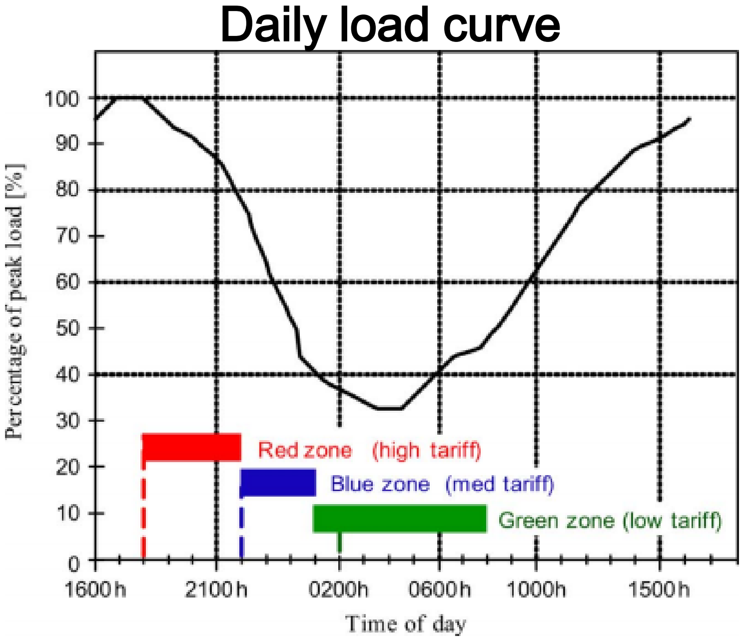


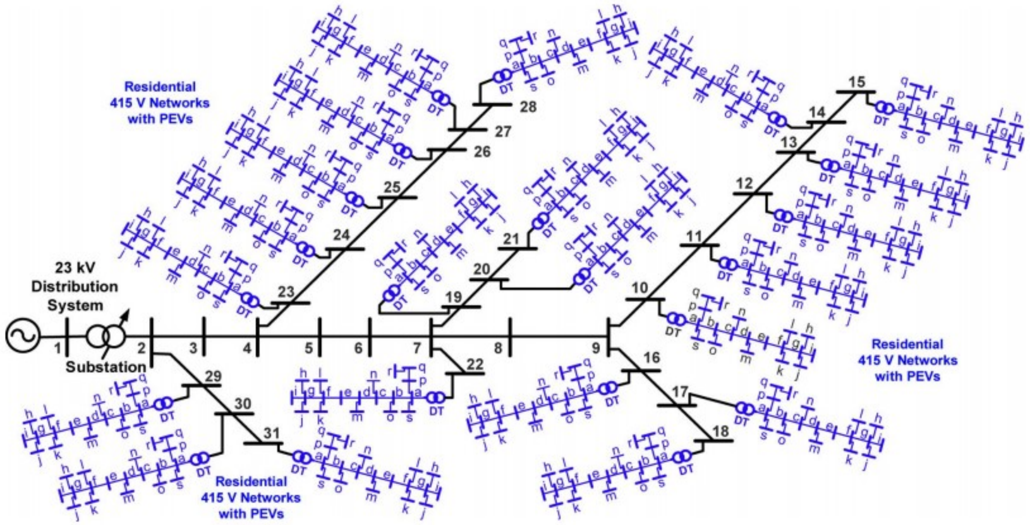
Number of households where voltage deviations larger than 10% are observed for smart charging

Source: Kevin Mets, 2011

CASE STUDY 2: COORDINATION OF MULTIPLE PLUG-IN EV CHARGING IN SMART GRIDS USING REAL-TIME SMART LOAD MANAGEMENT (RT-SLM) ALGORITHM







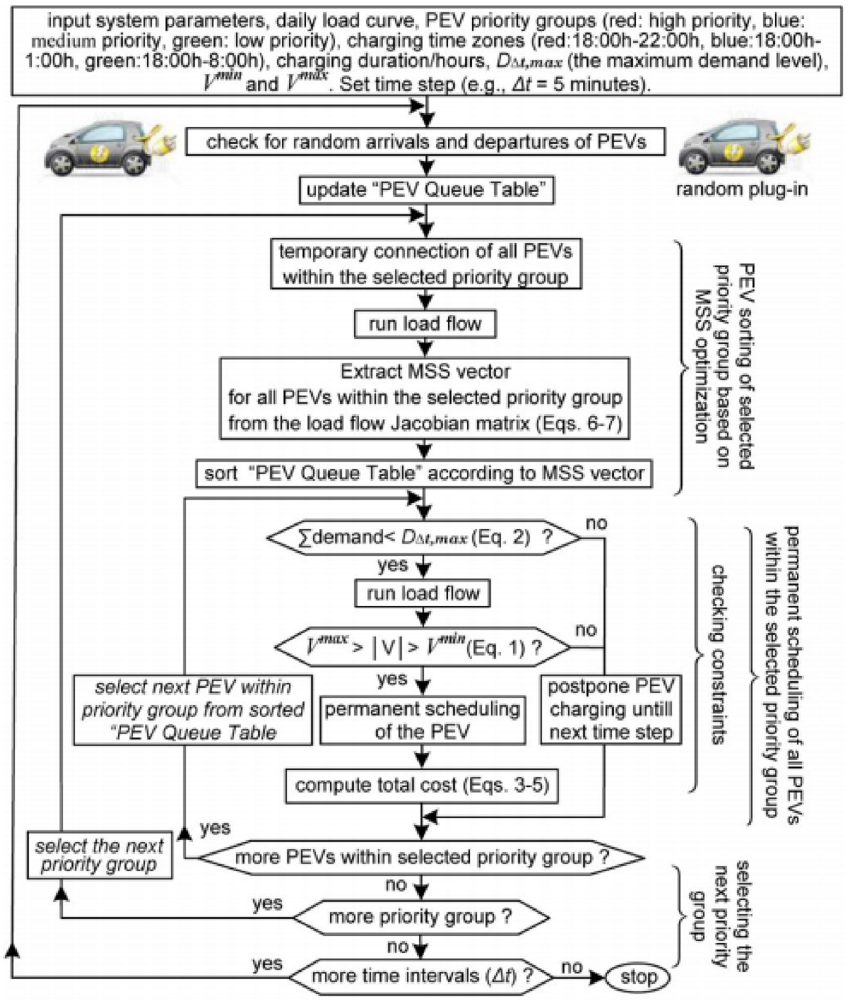
19 Node System	PEV Penetration Levels			
	16%	32%	47%	63%
a				
b				
c				
d				
e				
f				
g				
h				
i				
j				
k				
l				
m				
n				
o				
p				
q				
r				
s				

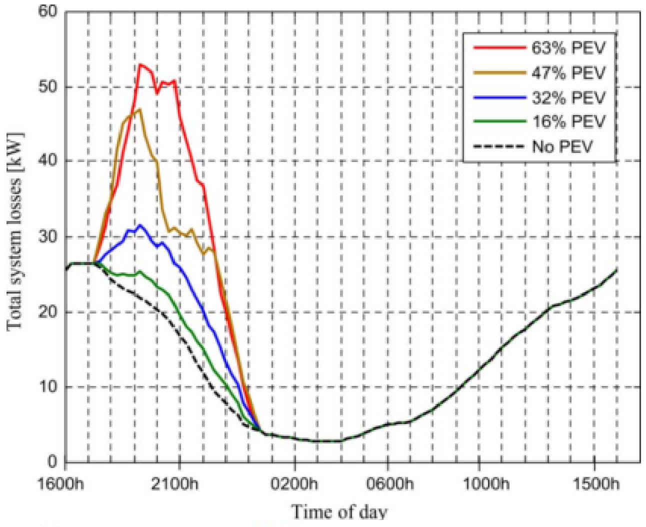
*) Boxes with no color indicate nodes with no PEVs present

- The 449-node smart grid distribution system topology consists of the IEEE 31-node 23-kV system with several 415V residential feeders.
- Each LV residential feeder has 19 nodes representing customer households with varying penetrations of PEV

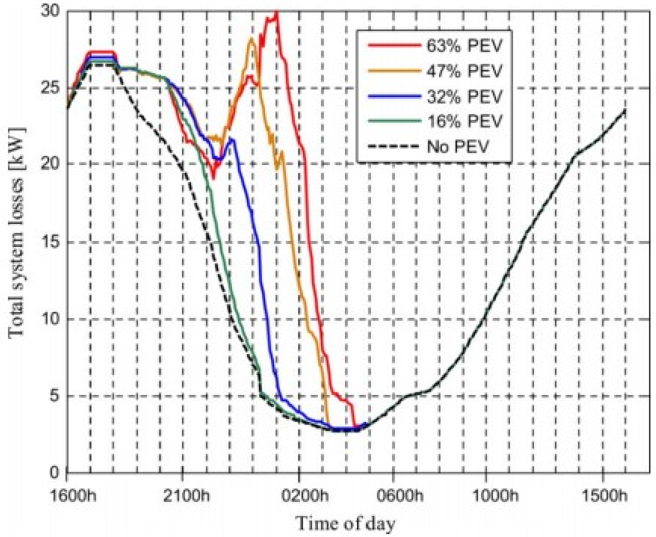
Source: Sara Deilami, 2011

CASE STUDY 2: COORDINATION OF MULTIPLE PLUG-IN EV CHARGING IN SMART GRIDS USING REAL-TIME SMART LOAD MANAGEMENT (RT-SLM) ALGORITHM





Impact of random uncoordinated PEV charging within 1800h-0100h on the total system power losses.



Impact of MSS-based RT-SLM coordinated PEV charging on total system power losses. Note the significant reduction in losses compared to random charging.

CASE STUDY 3:
EV CHARGING MANAGEMENT IN PV INTEGRATED DISTRIBUTION GRID REGARDING DSM

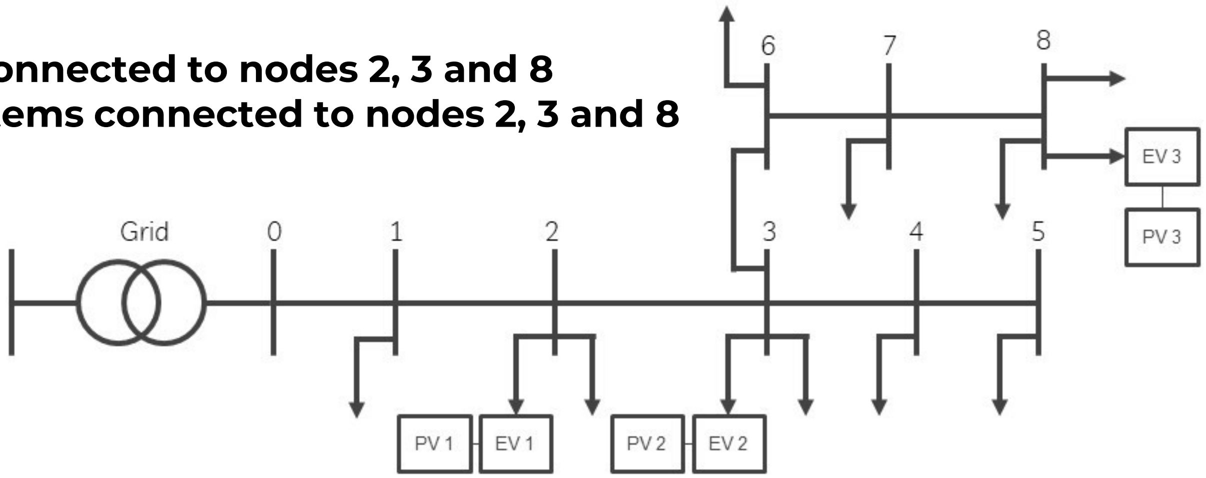
Objectives

Optimization of PEV charging scheme
With consideration of peak reduction, variance minimization based on dynamic pricing schemes

Evaluation of the influence of PEV with PV systems in a residential distribution network
An 8-node residential grid is simulated in 24 hours in 4 scenarios

Consideration the economic benefits of the optimal PEV charging scheduling
This act as an input for the residents and utility to balance the benefits

- **PEVs connected to nodes 2, 3 and 8**
- **PV systems connected to nodes 2, 3 and 8**



Source: V.N.H. Giang, 2021

CASE STUDY 3:
EV CHARGING MANAGEMENT IN PV INTEGRATED DISTRIBUTION GRID REGARDING DSM

$$\min_{x^i \in X^i} max\left(\sum_{i=1}^{J}\sum_{k=1}^{K^i} state_k^i x_k^i \tau + \sum_{k=1}^{K^i}\sum_{n=1}^{N} P_{baseload}{}_k^n - \sum_{k=1}^{K^i}\sum_{n=1}^{N} PV_{generation}{}_k^n\right)$$

MODEL 1

$state_k^i$	the plugging state of the of each connected PEV i at discretized time step k
τ	the duration of time steps (in hours)
x_k^i	the charging/ discharging rate of each connected PEV i at time step k (in kW)
$P_{baseload}{}_k^n$	the energy demand of the baseload at node n at time step k (in kWh)
$PV_{generation}{}_k^m$	the energy production of the PV system at node n at time step k (in kWh)
J	total number of connected PEVs
K^i	total number of time steps
N	total number of nodes in the distribution grid

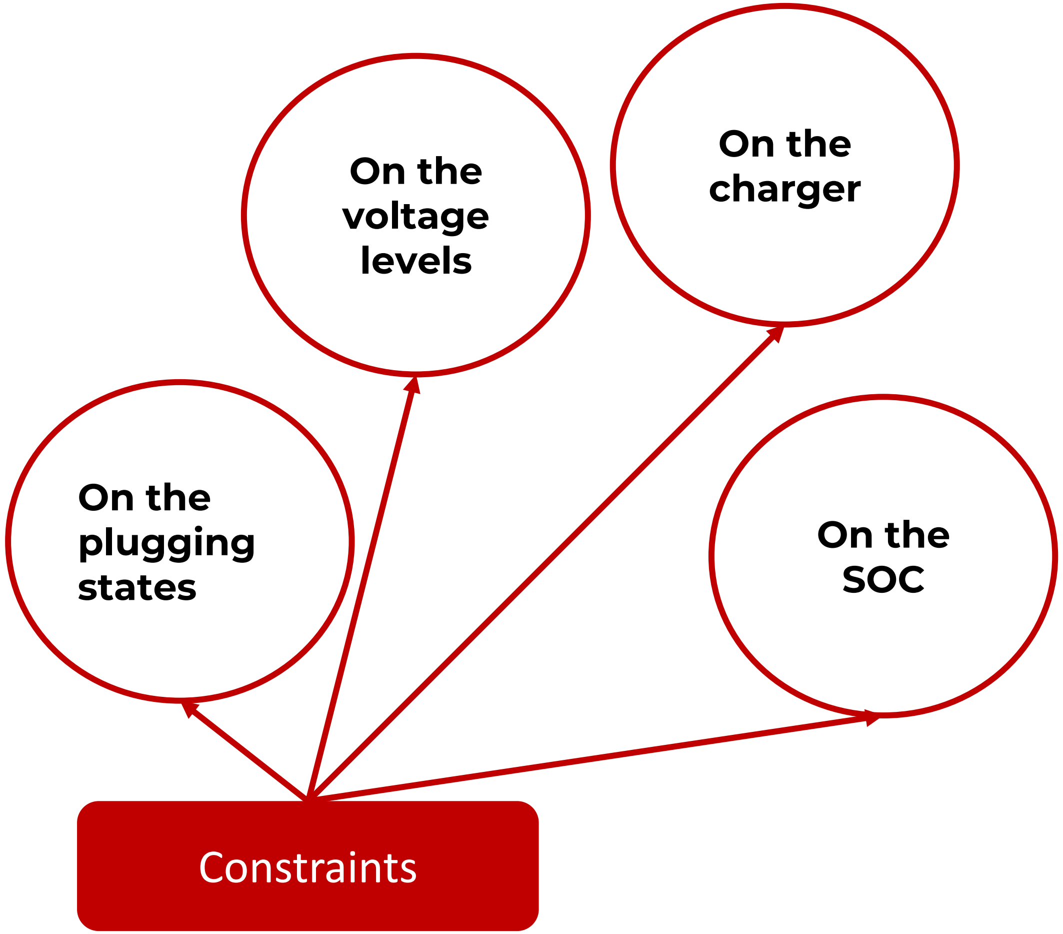
MODEL 1: Minimize load peaks

$$\min_{x^i \in X^i} var\left(\sum_{i=1}^{J}\sum_{k=1}^{K^i} state_k^i x_k^i \tau + \sum_{k=1}^{K^i}\sum_{n=1}^{N} P_{baseload}{}_k^n - \sum_{k=1}^{K^i}\sum_{m=1}^{N} PV_{generation}{}_k^n\right) \times (1-\vartheta) + \vartheta \sum_{i=1}^{J}\sum_{k=1}^{K^i} tariffs_k state_k^i x_k^i \tau$$

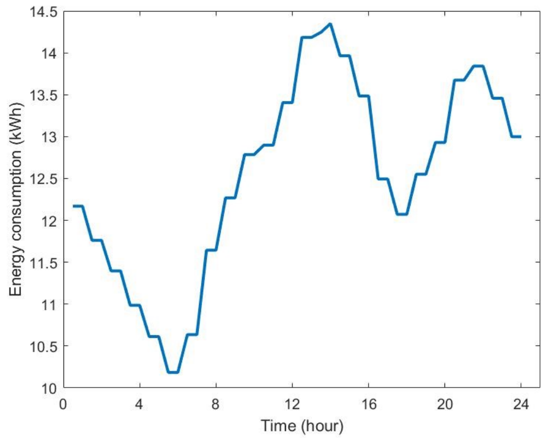
MODEL 2

$state_k^i$	the plugging state of the of each connected PEV i at discretized time step k
τ	the duration of time steps (in hours)
x_k^i	the charging/ discharging rate of each connected PEV i at time step k (in kW)
$P_{baseload}{}_n^i$	the energy demand of the baseload at node n at time step k (in kWh)
$PV_{generation}{}_m^i$	the energy production of the PV system m at time step k (in kWh)
J	the total number of connected PEVs
K^i	the total number of time steps
N	the total number of nodes in the distribution grid
$tariffs_t$	the tariff at time step k (in VND/kWh)
ϑ	coefficient for weighted average ($\vartheta \leq 1$)

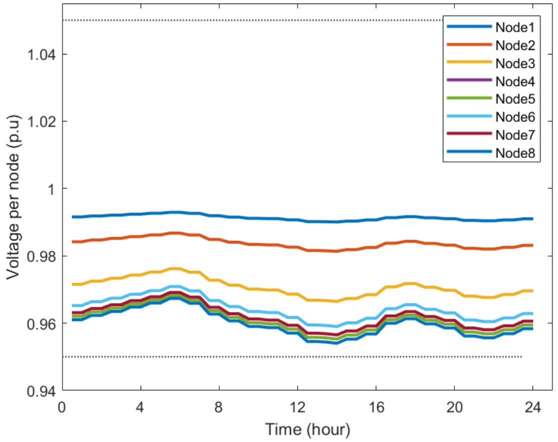
MODEL 2: Minimize voltage variance, lower the costs



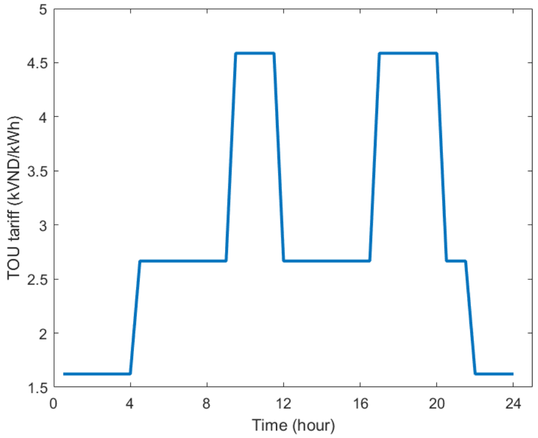
CASE STUDY 3:
EV CHARGING MANAGEMENT IN PV INTEGRATED DISTRIBUTION GRID REGARDING DSM



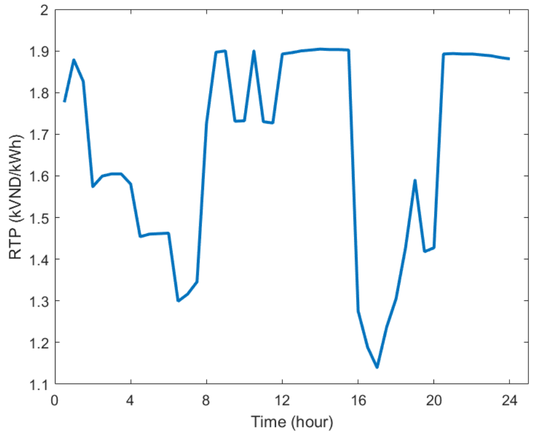
24-hour residential load profile



Node voltage profiles of baseload



TOU electricity tariffs



Calculated RTP based on locational marginal prices (LMP) on 7th August 2021 in Vietnam

CASE STUDY 3:
EV CHARGING MANAGEMENT IN PV INTEGRATED DISTRIBUTION GRID REGARDING DSM

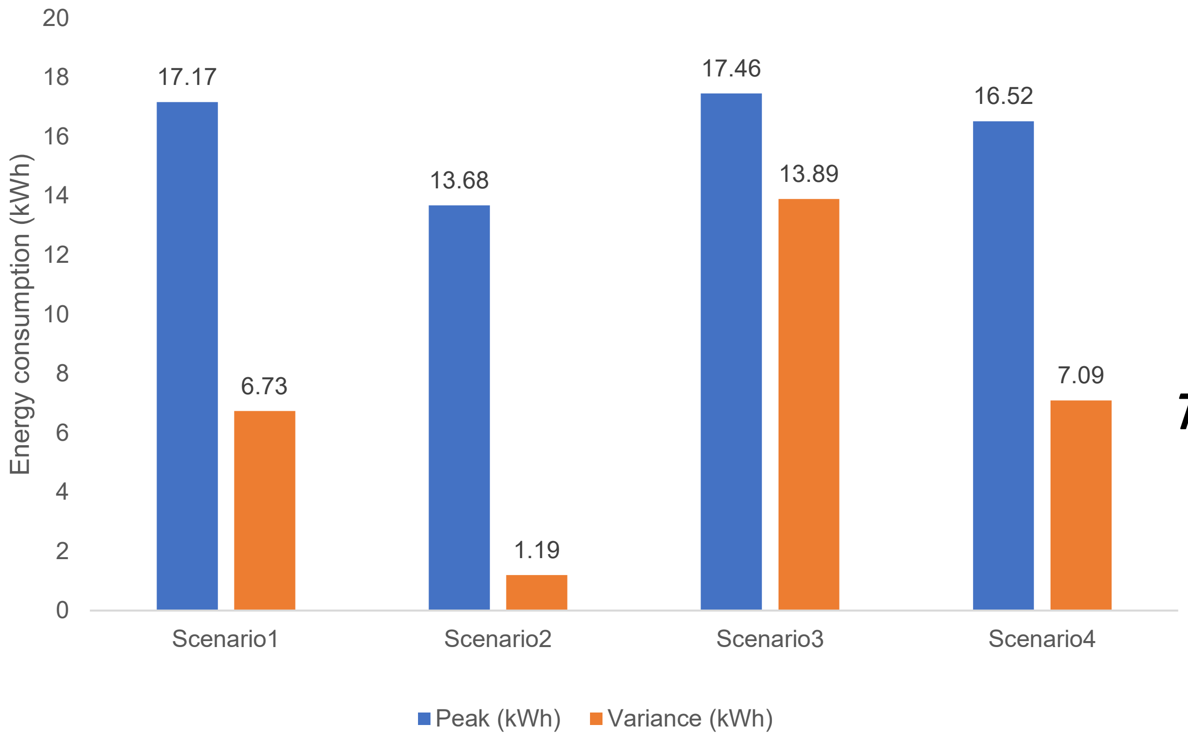
Scenario 1: Uncontrolled charging scheme, no V2G is applied

Scenario 2: Model 1 is applied to minimize peak demand, V2G is applied

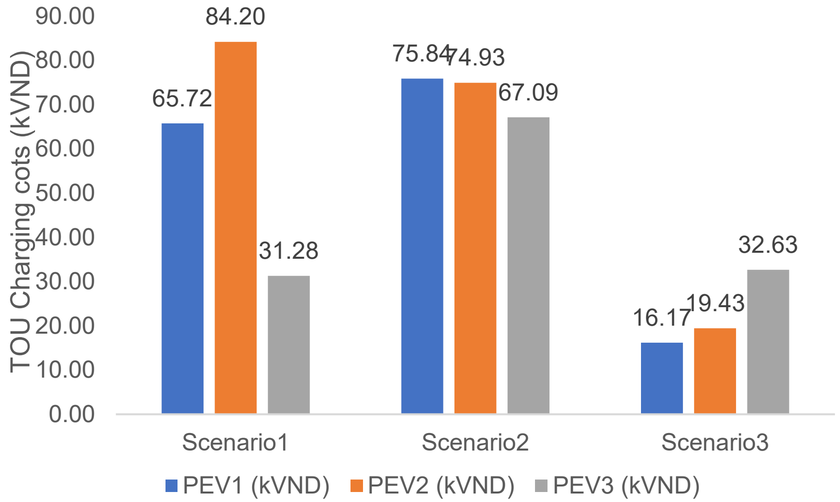
Scenario 3: Model 2 is applied to minimize the variance of the load profile and TOU charging cost, V2G is applied

Scenario 4: Model 2 is applied to minimize the variance of the load profile and RTP charging cost, V2G is applied

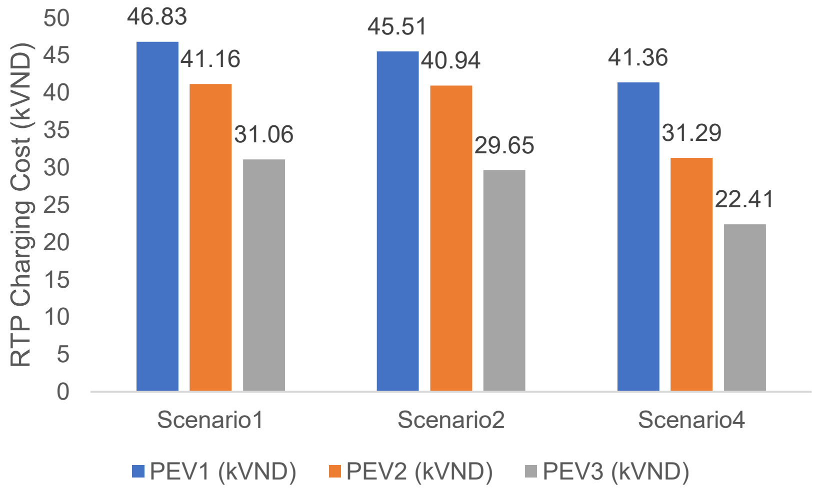
CASE STUDY 3:
EV CHARGING MANAGEMENT IN PV INTEGRATED DISTRIBUTION GRID REGARDING DSM



The peak value and variance of each evaluating scenario



The charging costs based on TOU of Scenario #1, #2 and #3



The charging costs based on RTP of Scenario #1, #2 and #4

CONCLUSION

- EV era comes
- EV brings and solves power system problem by V2G
- EV accompanied by RE

TS. Nguyễn Đức Tuyên
100RE Lab
Email: tuyen.nguyenduc@hust.edu.vn
Tel: 0986509059