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Plug-in Vehicles and Renewable Energy Sources for Cost and Emission Reductions

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Cyber Security and Privacy Issues in Smart Grids

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ECEN 689: Cyber Security of the Smart Grid
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Overview

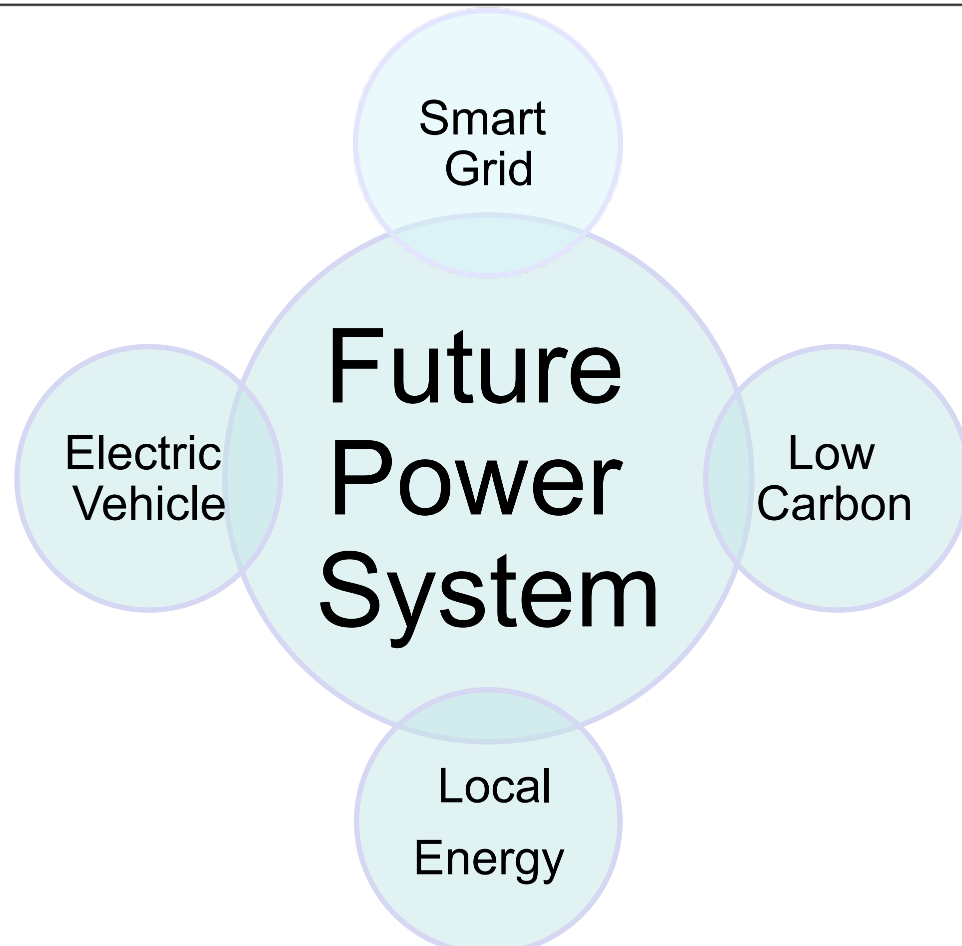
- Objective
- Cost and emission reduction analysis
- Cyber security issues
- Critical assessment
- Conclusion

ElectriNet

Integration of smart grid with

- **Electric transportation**
- **Low-carbon generation**
- **Local energy networks**

To enable interoperability and flexibility for competitive transactions.



Motivation

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- The rate at which global energy reserves are depleting is a major concern at economic, industrial, and societal levels.
- Power and transportation industry is responsible for **two third** of global carbon emission. A big ecological concern.

Partial solutions to the depletion of energy reserves and increase in emissions are

- **The integration of renewable energy sources(RES).**
- **The deployment of next-generation plug-in vehicles which include plug-in hybrid electric vehicles (PHEVs) and EVs with vehicle to grid (V2G) capability.**

Objective

- To understand the effect's of integration of RES and PHEVs with electric grid in terms of cost and emission reduction.
- To overview cyber security aspect of integration of PHEVs with smart grid.

PHEVs and RES for Cost & Emission Reductions

- The success of application of PHEVs and RESs to achieve emission and cost reductions depends on the maximum utilization of RESs.

A dynamic optimization approach is needed to optimize time-varying resources such as RESs and PHEVs in a complex smart grid.

PHEVs and RES for Cost & Emission Reductions

- RESs are used to reduce emission from the electricity industry.
- PHEVs are used to reduce emission from transportation industry..
- PHEVs are smartly used as loads, energy storages, and small portable power plants .
- Parking lots are used as virtual power plants.
- Onboard PHEV computer system communicates with utility to get real-time electricity pricing and convey vehicle battery's Status of Charge and vehicle owner's preferences.

PHEVs and RES for Cost & Emission Reductions

Category	Parameter	Equation
Source Power	Photovoltaic Power	$P\text{pv}(t) = A\beta\mu(t)$
	Wind Power	$P\text{wind}(t) = 0.5\alpha\rho(t)Av(t)3.$
	Non-renewable Power	$\sum Pi(t)$
	PHEVs as a Source	$\sum \xi Pvj(\Psi\text{pre} - \Psi\text{dep})$
Load Power	Load other than PHEVs	$D(t)$
	PHEVs as a load	$\sum \xi Pvj(\Psi\text{dep} - \Psi\text{pre})$
	Losses	
Emission and Cost parameters	Emission Function	$ECi\ (Pi(t))=\alpha i+\beta iPi(t)+\gamma iP^2\ i\ (t)$
	Fuel cost	$FCi\ (Pi(t)) = ai + biPi(t) + ciP^2i\ (t)$
	Starting cost for Thermal Power	$SCi(t)$

PHEVs and RES for Cost & Emission Reductions

Energy Equations

$$\sum_{i=1}^{N} P_i^{\max}(t) + P_{\text{pv}}(t) + \sum_{j=1}^{N_{V2G}(t)} \xi P_{v_j}(\Psi_{\text{pre}} - \Psi_{\min}) + P_{\text{wind}}(t)$$

$$\geq D(t) + Losses + R(t), \qquad \text{if GVs are S3Ps}$$

$$\sum_{i=1}^{N} P_i^{\max}(t) + P_{\text{pv}}(t) + P_{\text{wind}}(t) \geq D(t) + Losses + R(t)$$

$$+ \sum_{j=1}^{N_{V2G}(t)} \xi P_{v_j}(\Psi_{\text{dep}} - \Psi_{\text{pre}}), \qquad \text{if GVs are loads}$$

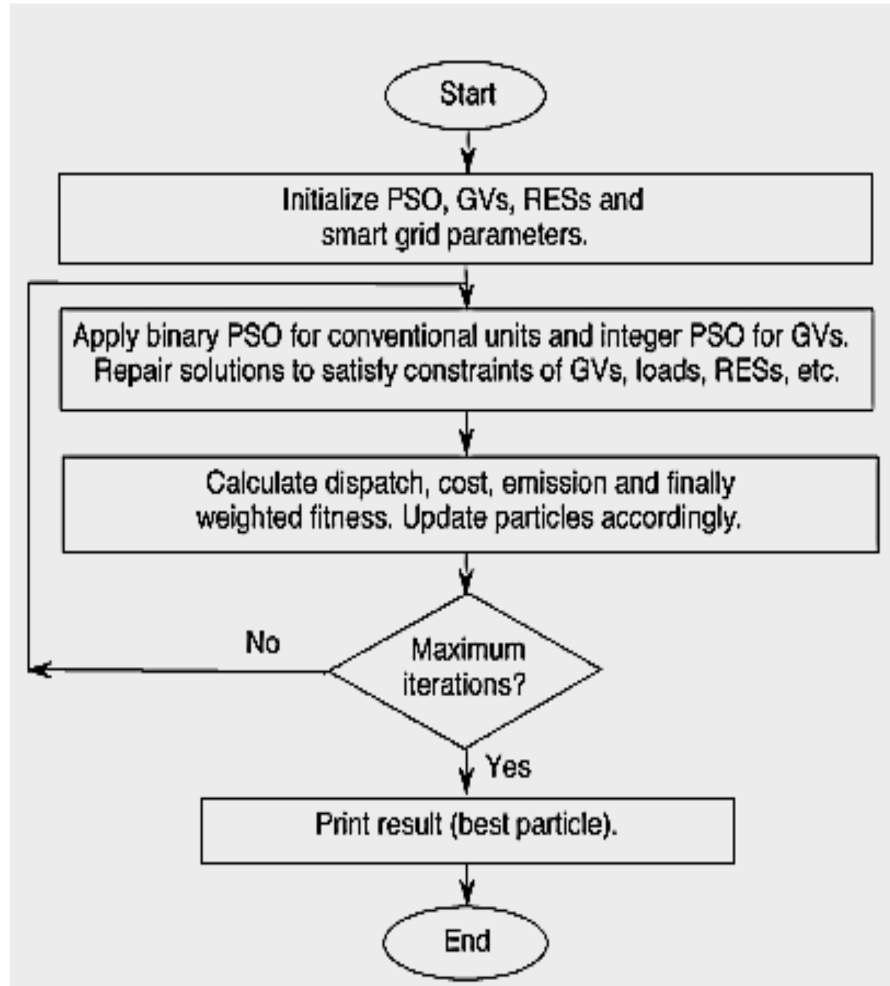
Optimization Equation

$$\min_{I_i(t), N_{V2G}(t)} TC = \mathcal{W}_c \times (\text{Fuel} + \text{Start-Up}) + \mathcal{W}_e \times \text{Emission}$$

PHEVs and RES for Cost & Emission Reductions

Optimization Algorithm

- Particle Swarm optimization algorithm is used.
- Each potential solution, called particle, flies in multidimensional search space with a velocity that is dynamically adjusted according to the flying experience of its own and other particles



PHEVs and RES for Cost & Emission Reductions

Results

Average distance covered by a vehicle	12,000 miles/year
Number of registered GVs per city (assumed)	50,000
Average distance covered by GVs per kWh	4.00 miles
Energy needed by a GV per day	8.22 kWh
Energy needed by 50,000 GVs per day	411 MWh
Typical off-peak load duration of a day	12 hours
Extra demand for GVs per off-peak hour	34.25 MWh
Typical percentage time a GV is parked (gridable)	95%
Average emission of a vehicle	1.2 lb/mile
Emission from 50,000 vehicles (transportation industry) over a year	326,678.766 tons

PHEVs and RES for Cost & Emission Reductions

Load levelling

- Power plants can be run below their normal output, with the facility to increase the amount they generate almost instantaneously.
- Extra Emission from power plant due to PHEVs/ year is **285,425.95 tons**.

- **Running PHEVs with load leveling model will increase both cost and emission of power industry.**

PHEVs and RES for Cost & Emission Reductions

Smart grid emission reduction

- Emission reduction/year from power plant due to PHEVS and RES is **409,493.86 tons.**
- Total Emission reduction/year from power plant and transportation is **736,172 tons**.

- **Total Operational Cost reduction per day is $179,071.95**

PHEVs and RES for Cost & Emission Reductions

Smart grid cost analysis

- Extra energy needed for Smart Grid model is 750MWH.

Total Capital investment in power system for the smart grid model is $225.50 Million.

PHEVs and RES for Cost & Emission Reductions

Conclusion

- The smart grid model with PHEVs and RES will ensure huge emission reductions.
- Reliability of the power system, most likely will decrease.
- In the ideal case, it would take at least 8 years to recover capital investment due to integration of RES into the grid.

Cyber Security & Privacy Issues in Smart Grids

- The paper presents overview of cyber security and privacy issues related to smart grid.
- The security issues with PHEVs is discussed in **Guidelines for smart grid cyber security (vol. 1 to 3) by US NIST**.
- The next part of presentation aims to find solution of cyber security and privacy issues for integration of PHEVs with smart grid using the paper **Cyber Security and Privacy Issues in Smart Grids.**

Privacy Issues

Privacy Concern

- Essential to secure consumer information like name, vehicle information, address and energy usage during PHEV registration and enrollment.

- US NIST considers privacy as a bigger concern with PHEVs, as breach in privacy could result into leak in vehicle position which enables the culprit to track the vehicle.

Privacy Issues

Solution

- Conceptual model **SmartPrivacy** can be used to ensure privacy while having full functionality of smart grid.

SmartPrivacy model advocates having

- Limited and related access to third parties on consumer information.
- Secure communication channels.
- Anonym zed identity of the consumer.
- Stringent laws on third parties to ensure privacy.

Cyber Security Issues

Advanced Metering infrastructure(AMI) issues concern

- When customers have the ability to generate and consume power, **Net metering** is installed to measure power flow in each direction and net power flows occurred.
- In **Feed-in tariff pricing** the generation from customer PEV has a different tariff rate than the customer load tariff rate during specific time periods.
- **Confidentiality and integrity** must be maintained for ensuring privacy and proper operation of smart grid.

Cyber Security Issues

Advanced Metering infrastructure(AMI) issues solution

- For authentication, methods like **High assurance boot** could be used as PHEVs will be validated once connected to charging station or smart grid. Common method of key encryption can also be used.

- For confidentiality and integrity **AES encryption** can be used with less centralization and more persistent connectivity than current approaches.

Cyber Security Issues

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Dispatching and Management Issues Concern

- Attacker can attack grid by attacking energy management system (EMS) via faking meter data and misleading EMS by state estimator to make bad decisions. This attack may affect PHEVs and RES and lead to improper operation.
- Data encryption and digital signatures are required in sensors to secure communications.
- Device or system may be ”locked out” at the time of security breaches or when an emergency occurs .

Cyber Security Issues

Dispatching and Management Issues Solution

- Encryption can be used to protect a state estimator and from attacks and false data injection can be prevented.
- Design a bypass means for emergency while remaining secure in daily operations.
- PKI (Public Key Infrastructure) can be used for secure sensor data communication.

Cyber Security Issues

Demand Response Issues Concern

- Tampering with information of real time pricing (RTP) may cause financial and legal problems. This may also affect the load as smart chargers of PHEVs can react to low prices and suddenly the load increases.

- Malware may infect the grid, indicating false trend of supply and demand. This causes substantial damage to the power delivery system.

Cyber Security Issues

Demand Response Issues Solution

- Deploying trusted computing platforms i.e more secure communication protocols can be the solution to problem of tampering with real time pricing and infection by malware in the system.

Critical assessment.

- Cyber attacks are characterized and real examples are given to emphasize the threats on the modern power grid.
- A suitable solutions are provided cyber attacks on the electricity market.
- However, detailed characterization of all components related to PHEVs is required to accurately find vulnerabilities and determine potential cyber attacks.
- During Cost and emission analysis only thermal power plants are taken into account and the cost of investment for PHEVs is missing.

Conclusion

- PHEVs with RES can become the alternative for emission reduction which is critical for environment betterment.
- Initial investment for embedding PHEVs and RES is huge and becomes the biggest obstacle for their implementation.
- Research about this topic is in initial stage and lot of work need to be done related to cyber security and reliability aspects.

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Thank you!

Questions?