Bayesian Network for Using Electrical Vehicles as Power Storage

First Author: Asoc. Prof. Gülgün KAYAKUTLU
Co-Author: Nilay KAMAR
Co-Author: Prof. Dr. Özgür KAYALICA
1. Urge for EV usage
2. Bayesian Belief Networks
3. Case
4. Preliminary Scenarios
5. Conclusion
FACT: 78.6 000 MW Power (Turkey April-2017) 6% RES

- Continuous Energy Supply
- Decreased CO₂ emissions
- Confidence in Renewable energy resources

Distribution of carbon emission in Turkey (IEA, 2014)
It is clear that the most energy consuming sector in Turkey is in industrial zones.
Smart Micro Grids

- Elimination of current fluctuation, interruption or disruption
- Preventing peak loads
- Preventing environmental pollution
- Providing stable electrical supply
- Enhancing reliability and flexibility
- Economic
- Preventing current losses due to long distribution lines
- Preserving system from blockout
Vehicles as Storage

The uncertainty of renewable energy resources

Power Storage

- Employee Shuttles
- Urban cars
- Trucks

Stay during the day as majority of the cars used mainly out of the zone daily or long duration, but parked in the zone
Considerations with EV

- Demand
- Uncertainty of capacities
- Grid connection
- Peak hours
- Electricity price
- Emission margin
- Energy storage capability
- Amount of Inactive EVA
- Self Sufficiency
Methodology

Cognitive Map

Bayesian Belief NW

Scenario Analysis
"The demonstration of causal relations between the elements of a given community to be used to make decisions in social and political systems" (Axelrod, 1976)

Fig. 4: A cognitive map

Table 1: A pairwise comparison matrix

<table>
<thead>
<tr>
<th></th>
<th>K1</th>
<th>K2</th>
<th>K3</th>
<th>K4</th>
<th>K5</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>K2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>K3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
</tr>
<tr>
<td>K4</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>K5</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
</tbody>
</table>
Bayesian Theorem explains the relationship between conditional probability and marginal probabilities under the probability distribution of two variables that are related to each other.

- \( P(W) \) is the prior assumption of a parameter before any calculation from the probability from the data,
- \( P(D|W) \) is called the likelihood. It is the probability of the data \( D \) given \( W \).

\[
P(W|D) = \frac{P(W)P(D|W)}{P(D)}
\]

Fig.2: A Bayesian Network
Case: Gebze Industrial Zone

Demand: 546 Mw Electricity By 224 Manufacturing Companies metal, chemical, food from major industries
GIZ Microgrid

With 1 Nat-gas turbine of 12 MW, capacity 12 Wind Turbines of 3.4 MW capacity and PV of 6 MW 25% cost reduction 30% Carbon emission reduction (Öztürk, Kayakutlu, 2017)
Criteria Chosen by Experts

- Unit electricity price
- Amount of electricity demand
- Storage cost
- Electricity cost
- Storage with EVs
- Storage with battery
- Environmental consciousness
- Cost of air pollution
- # of EVs in organized industrial zones
- Technological competence
- Storage capacity within the working hours
- Storage capacity after the working hours
Cognitive Map for Gebze/Istanbul
Bayesian Belief Network for Gebze Istanbul
Bayesian Belief Initial State
Optimistic Scenario with EVs
Optimistic Scenario with Batteries
Pessimistic Scenario with EVs
Pessimistic Scenario with Batteries

- environmental_consciousness:
  - Low: 100
  - High: 0

- the_number_of_EV:
  - Low: 100
  - High: 0

- technological_competence:
  - Low: 100
  - High: 0

- amount_of_electricity_demand:
  - Low: 55.0
  - High: 45.0

- storage_capacity_within_hours:
  - Low: 88.0
  - High: 12.0

- storage_capacity_after_hours:
  - Low: 75.0
  - High: 25.0

- unit_electricity_cost:
  - Low: 49.8
  - High: 50.2

- cost_of_air_pollution:
  - Low: 87.0
  - High: 13.0

- electricity_cost:
  - Low: 37.9
  - High: 62.1

- storage_cost:
  - Low: 19.9
  - High: 80.1

- storage_with_EV:
  - Yes: 0
  - No: 0

- storage_with_battery:
  - Yes: 0
  - No: 0
Results & Discussions

**Optimistic Scenario**
- Electricity cost: 46% for 'EVs vs 79% for battery
- Storage cost: 39% for 'EVs vs 49% for battery

**Pessimistic Scenario**
- Electricity cost: 20% for 'EVs vs 76% for battery
- Storage cost: 38% for 'EVs vs 56% for battery
Conclusions for an Industrial Zone

- Scenarios indicate lower power and storage costs
- Continuous energy system with lower carbon emission
- Intelligent power management would be possible with this “vehicle to grid” model
- Continuing with real numbers and new scenarios
Suggestions for Future Research

- Different battery types
- Compare high tech EVs
- Charging Implications
- Compare Residential and Industrial uses
Objective for Our Future:

Not Just Energy Efficiency
Not Just Renewable Energies
Not Just Self Sufficient Energy use

Standalone Ecosystem

Green & Eco-Designed Technologies
Flexible Management
Environmental Policies
Industrie 4.0