Institute for
Renewable and Sustainable Energy Systems

Optimization of Distribution Transformer Energy Management System with Stationary Battery and Electric Vehicle Charger

Linear programming for optimal DTR scheduling and battery storage operation

Parinya Sonsaard, Johannes Dorfner, Thomas Hamacher

Challenges for future distribution grids

Electric mobility is going to cause additional loads. Future electricity grids thus might need to satisfy higher demand peaks. This study is based on a residential load curve of the north of Thailand that is multiplied by a measured utilization factor of 160 kVA (31.60%). This leads to a base load (43.34 kVA peak) and simulated EV home charger loads (3.5 kVA peak/unit). The area that we study is a remote area with a single distribution line (about 150 km). **Figure 1** shows the investigated system together with all technologies investigated. Electricity supply today mainly relies on the **distribution grid**.

Investment and scheduling optimization

The objective is to minimize the total cost, subject to base load and EVs home charger load. The total cost, including investment cost for generation capacities, operation cost, maintenance cost, fuel cost is modelled as a **linear program**. This study finds a **cost-minimal investment and scheduling strategy** for the distribution transformer (DTR) and an optional stationary high-power battery.
Constraints are demand satisfaction for a full year in hourly resolution (8760 time steps) and the available supply and storage options (different per case).

Investigated scenarios

In the base scenario, the following supply options are available: Purchasing the **national electricity mix**, local generation (distributed generation: DG) through **photovoltaic (PV), biomass, and diesel generator.** Only running costs are considered.

Table 1 summarizes all investigated load and supply combinations. **Figure 2** shows the three different loads. Cases 4-7 include **DG**, cases 5-7 include **optional battery storage**.

EV home charger will coming in near future, in this study we focused on coordinated and uncoordinated EV home charger. Uncoordinated are in case of all customers preferred to charge at the time they arrived their home that they don't care about peak demand or tariff. Coordinated are in case of the utility care about peak demand and customers care about tariff, the customers can plug in the EV home charger at the time that they arrived home and let the utility system manage schedule to charge.

Results

Figure 3 summarizes costs and energy mixes of all 7 investigated scenarios. Cases 1, 4, 5 only have **base load**, thus lower absolute costs. Specific costs for produced electricity range from 0.04 €/kWh (case 4) to 0.10 €/kWh (case 1).

In terms of energy, cases 4 & 5 show much more generation than demand; the distribution line is only used for exporting excess electricity from DG; the region becomes a power and energy exporter. Cases 2, 3, 6, 7 show the more demanding Base + EV loads, hence the higher generation and costs. Unlike in the base load scenarios, the distributed generation capacities only can contribute a small share to demand satisfaction; most electricity must be bought from the grid.

An option to extend the 32 kWh stationary battery was not used for current investment costs of 856 €/kWh (10 year lifetime, 10% depreciation). When reduced to 10 % of this value, the optimal storage size increases to over 300 kWh, storing PV for charging.

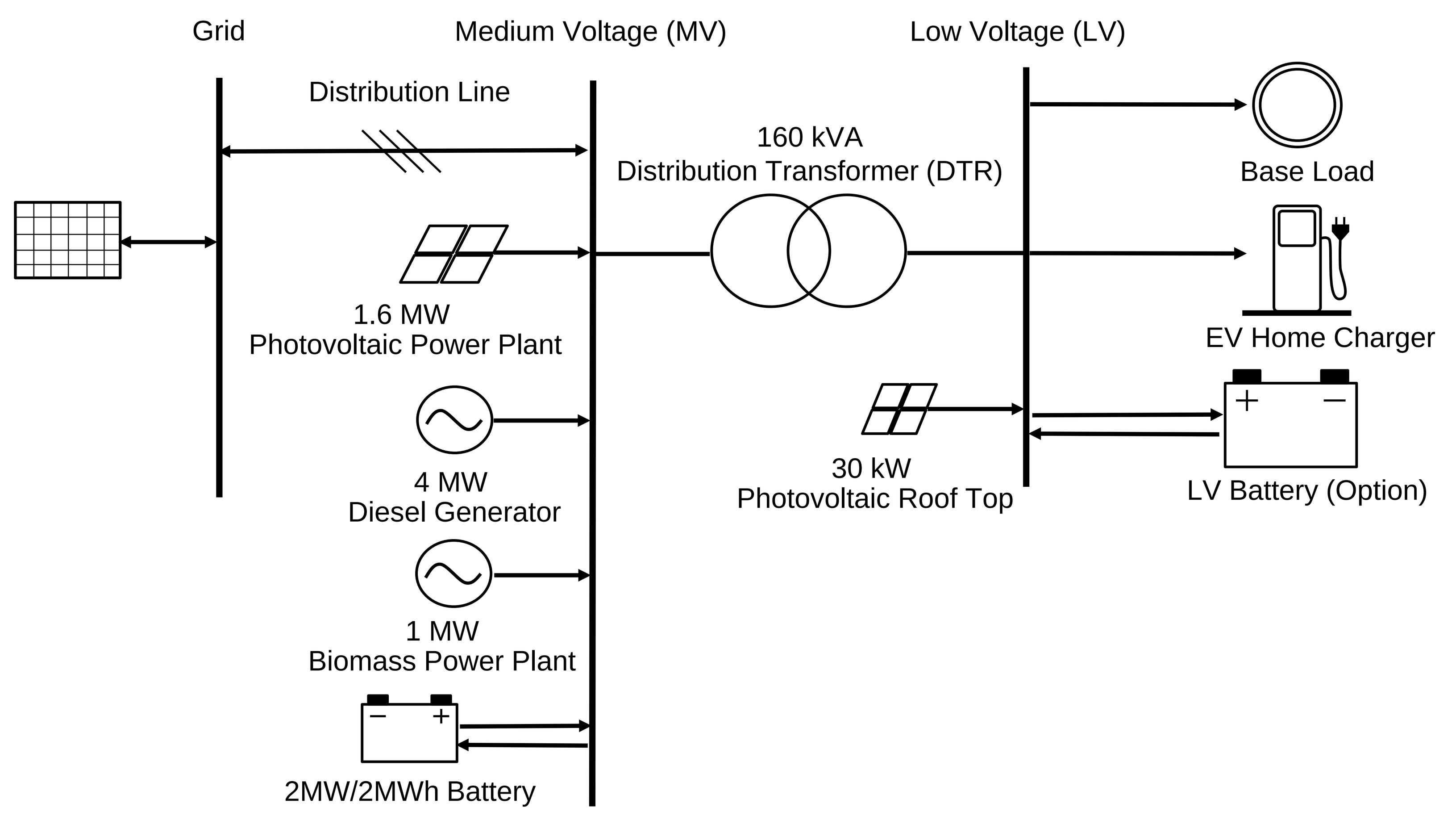

Figure 1: Power system schematic with grid connection, distributed PV, biomass, and diesel generation, batteries, household consumers and additional electric vehicle (EV) loads.

Table 1: Investigated load and technology scenarios

Case 1: Base load	Case 5: Base load + DG + Battery
Case 2: Base load + Unco. EV	Case 6: Base load + DG + Battery + Unco. EV
Case 3: Base load + Co. EV	Case 7: Base load + DG + Battery + Co. EV
Case 4: Base load + DG	

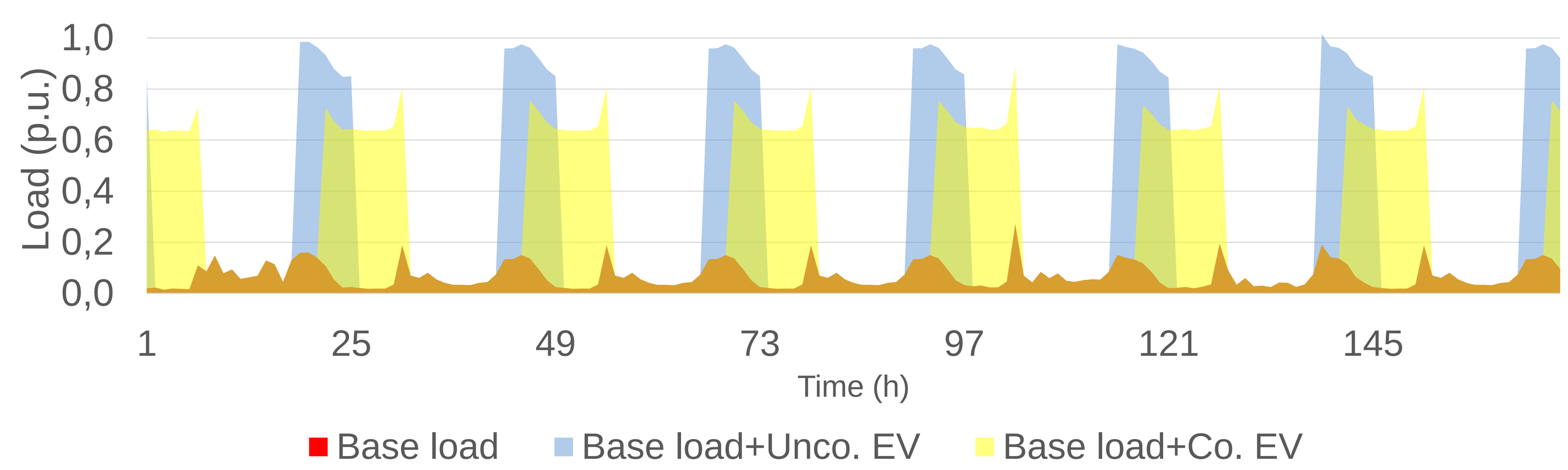

Figure 2: Normalized load curves for the 3 investigated load scenarios with and without EVs

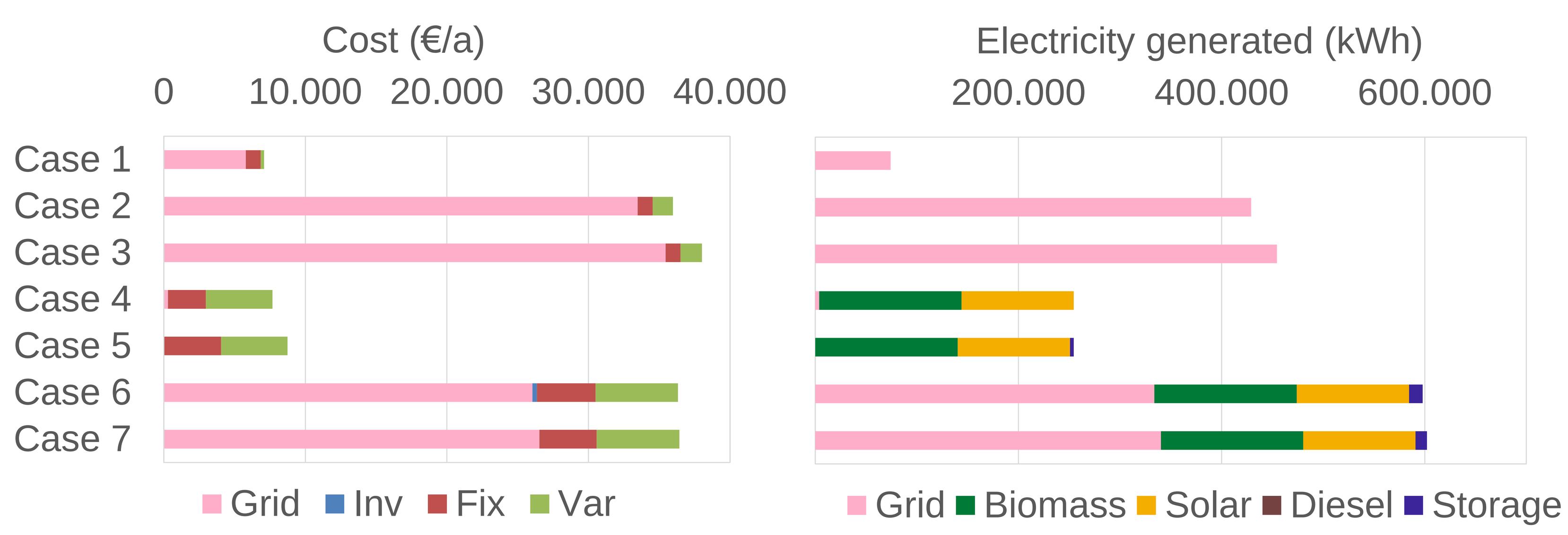

Figure 3: Total annual costs and electricity mix by investigated scenario

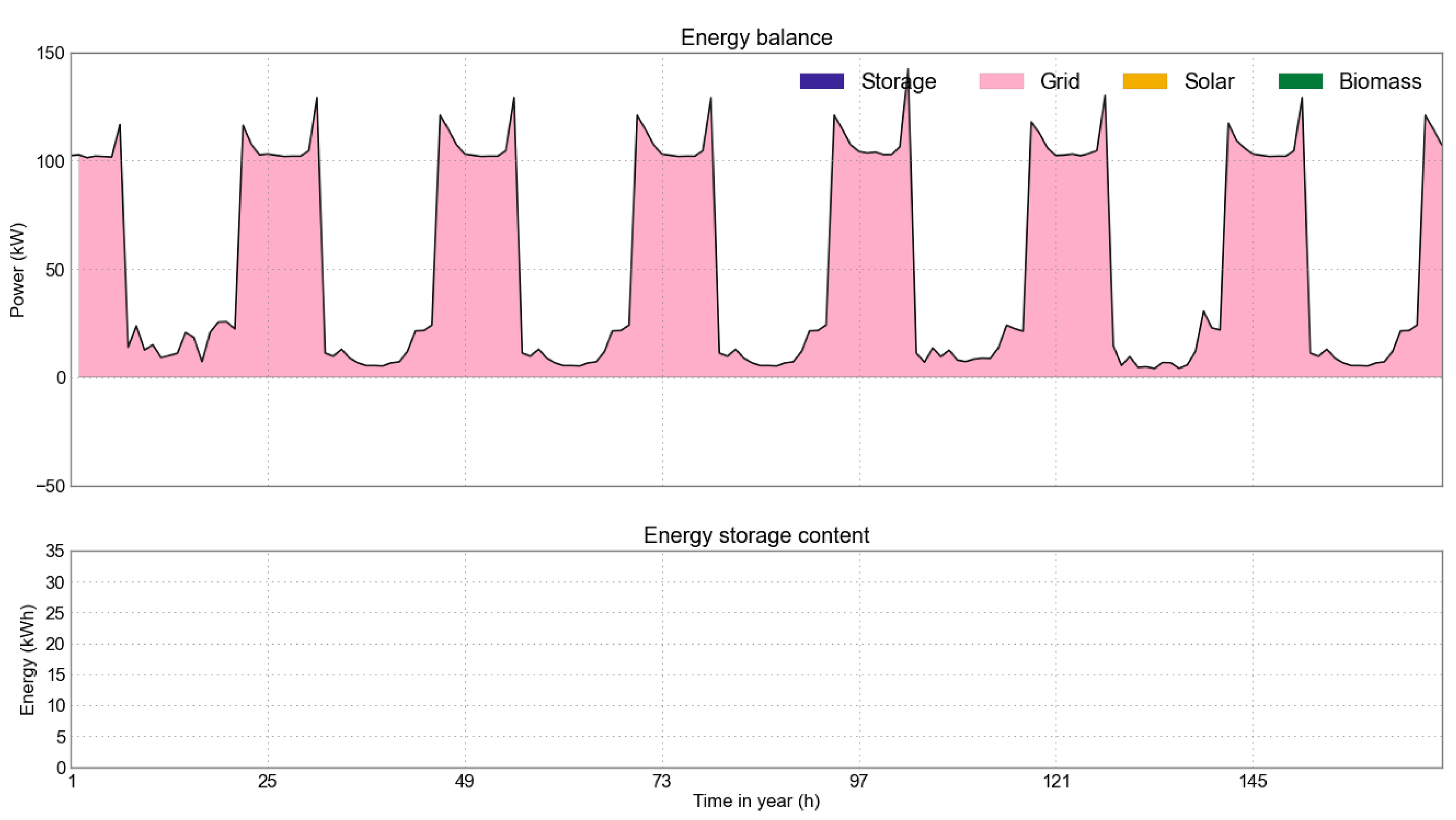

Figure 4: Exemplary week of energy production, storage and consumption (black) in Case 3

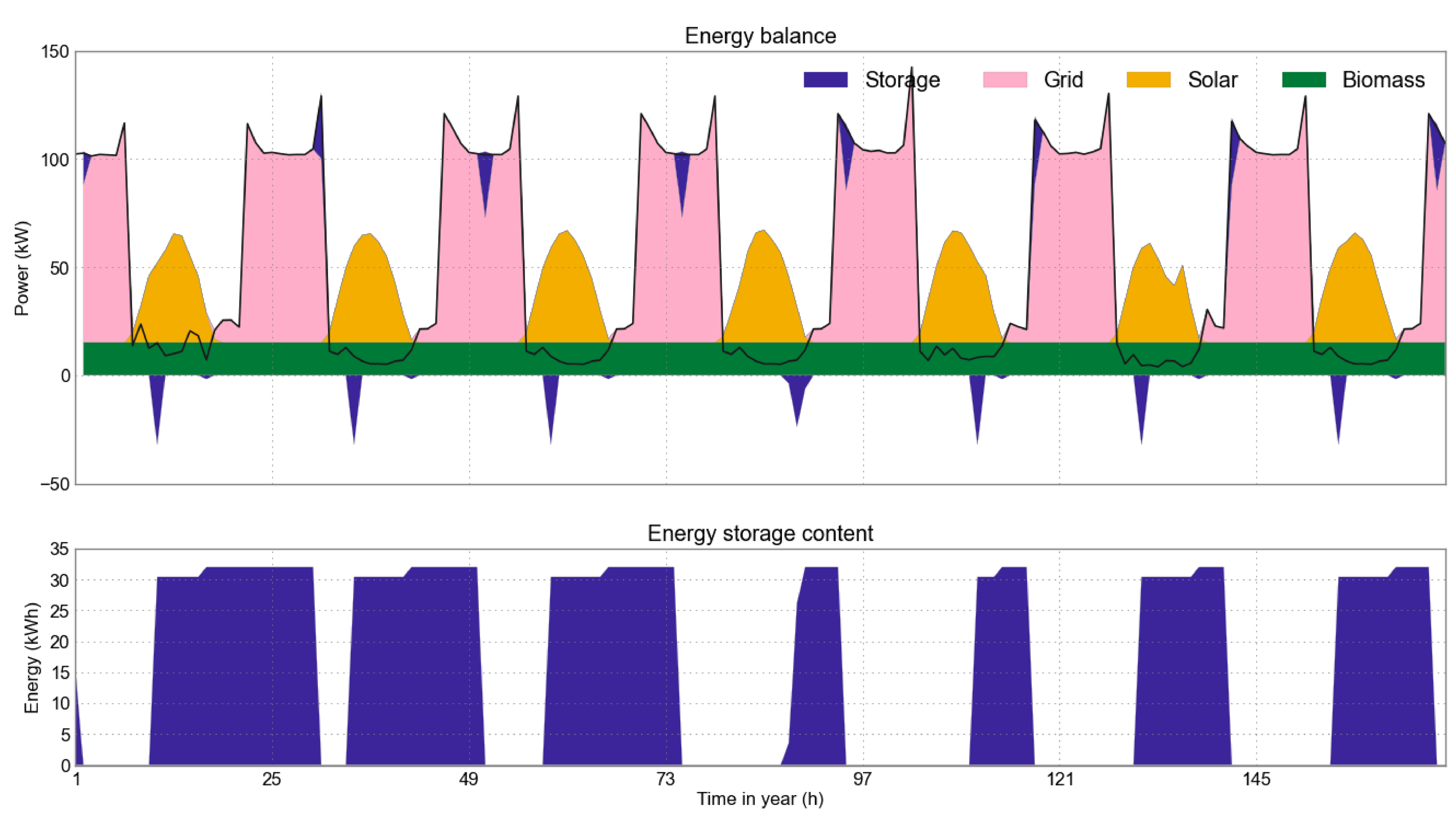

Figure 5: Exemplary week of energy production, storage and consumption (black) in Case 7