OPERATIONAL FLEXIBILITY OF ELECTRIFIED TRANSPORT AND THERMAL UNITS IN DISTRIBUTION GRID

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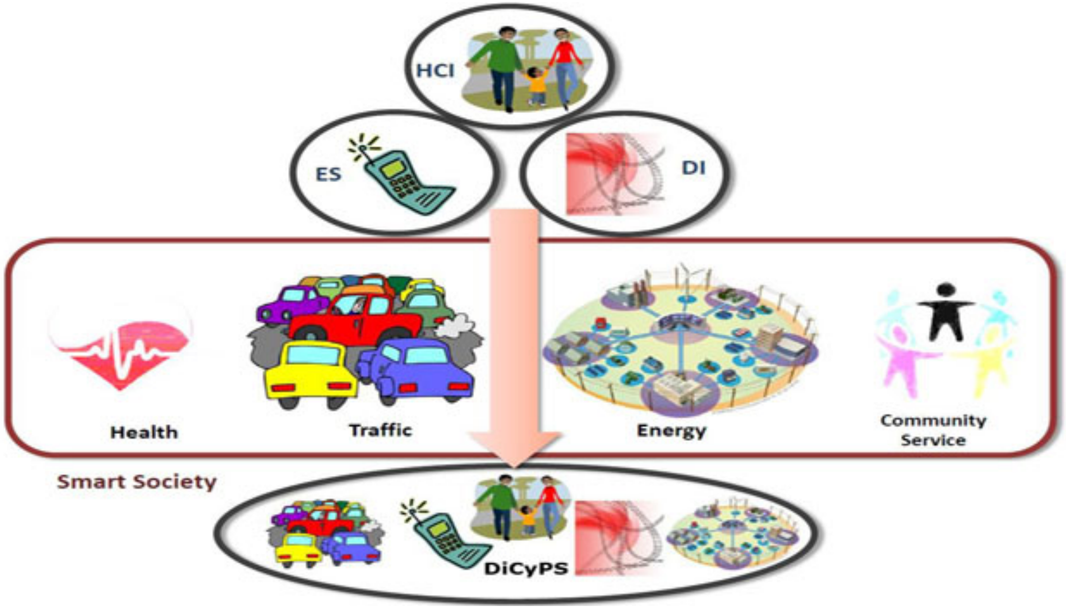
Acknowledgement



- Linking Heating, Transportation and Electricity System
- Electricity, transportation and thermal energy systems are complex and offer numerous opportunities for deep integration

Reference: https://www.iea.org/publications/freepublications/publication/LinkingHeatandElectricitySystems.pdf

Partners: 20+ Partners across Denmark and Europe

Link to project website: DiCyPS

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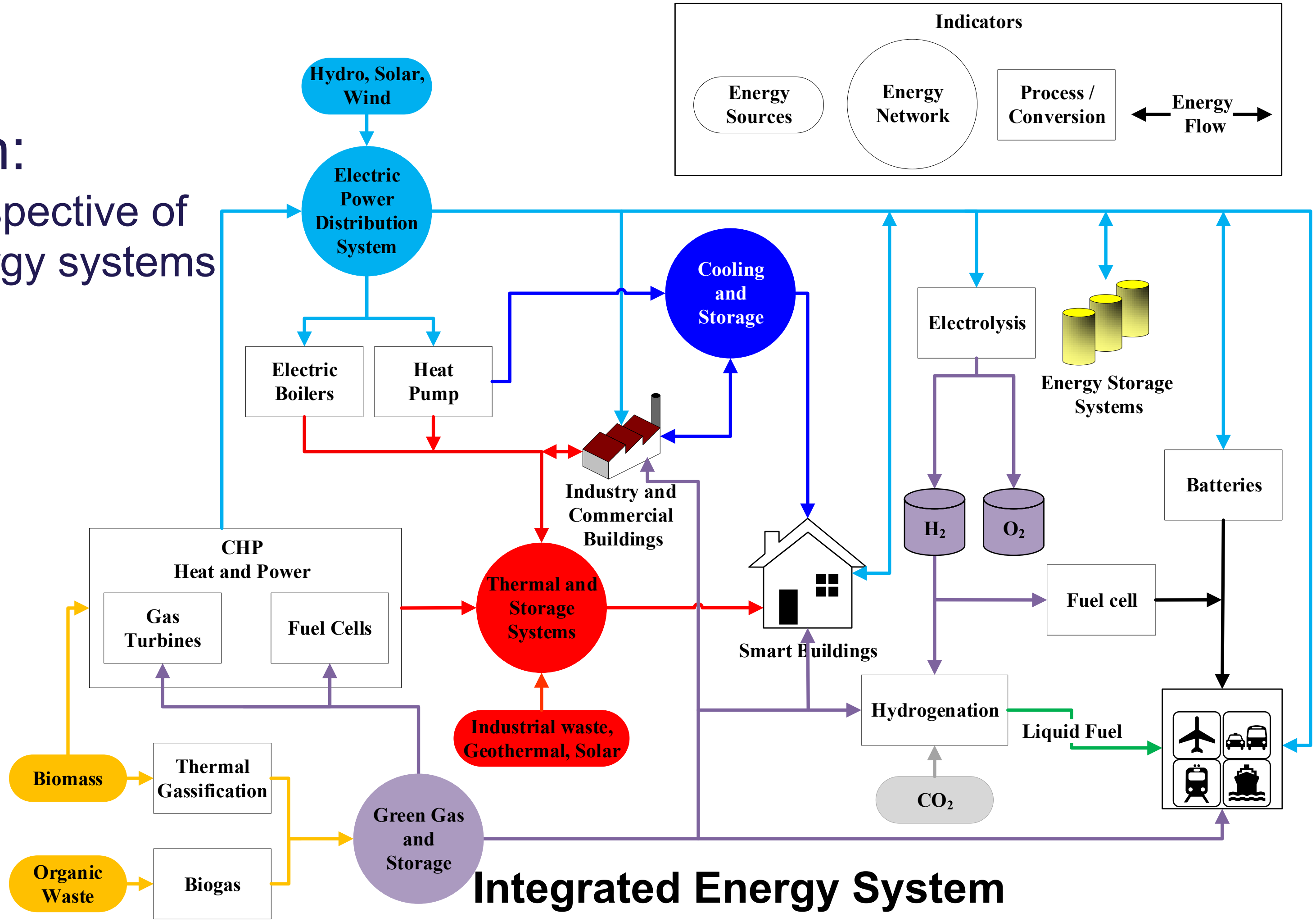
Contents

Introduction:

The future perspective of integrated energy systems in Denmark



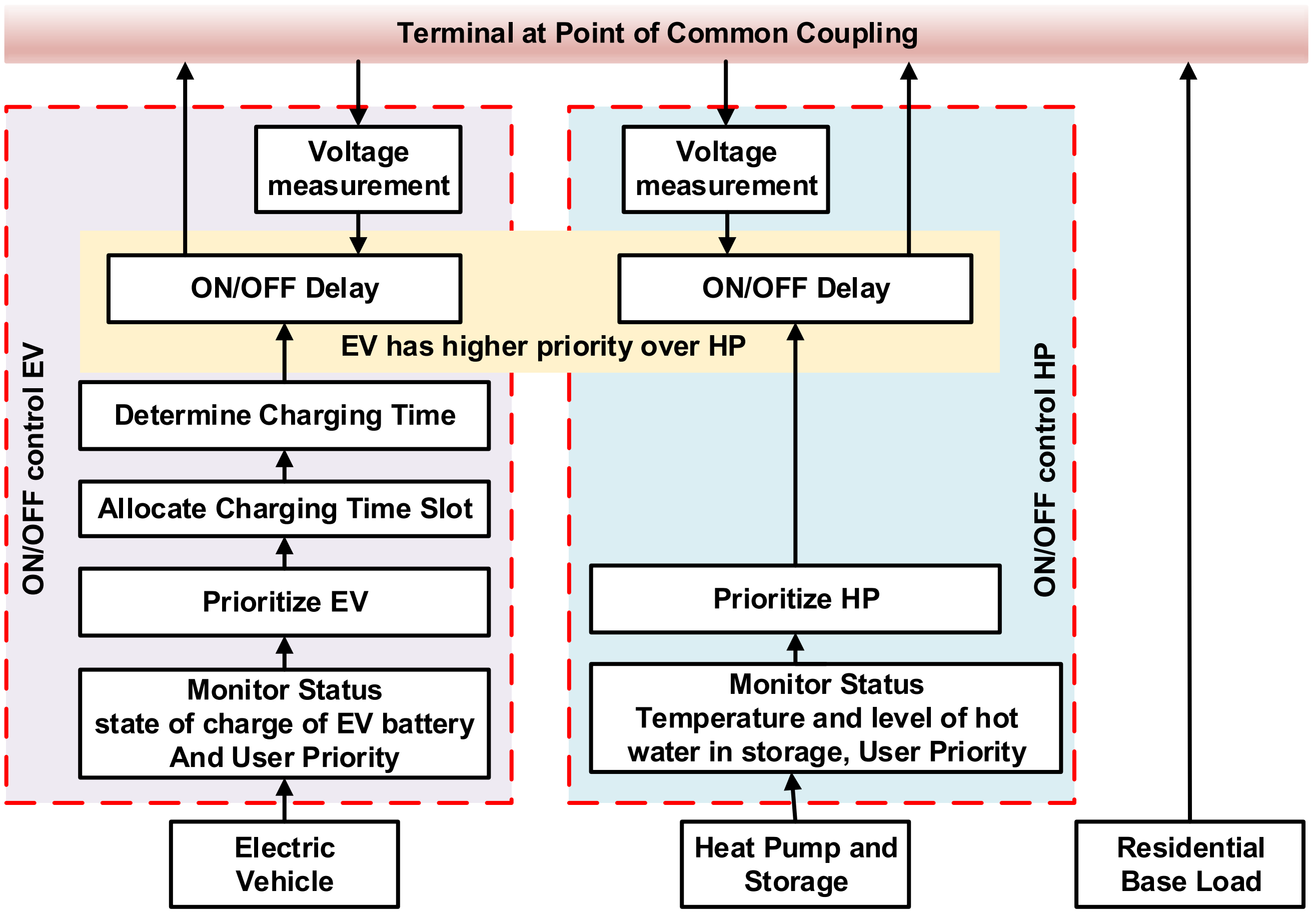
Integrated Energy System

The integrated energy system with energy production, distribution, storage, and consumption from different sector are linked together with operational flexibility in an intelligent way

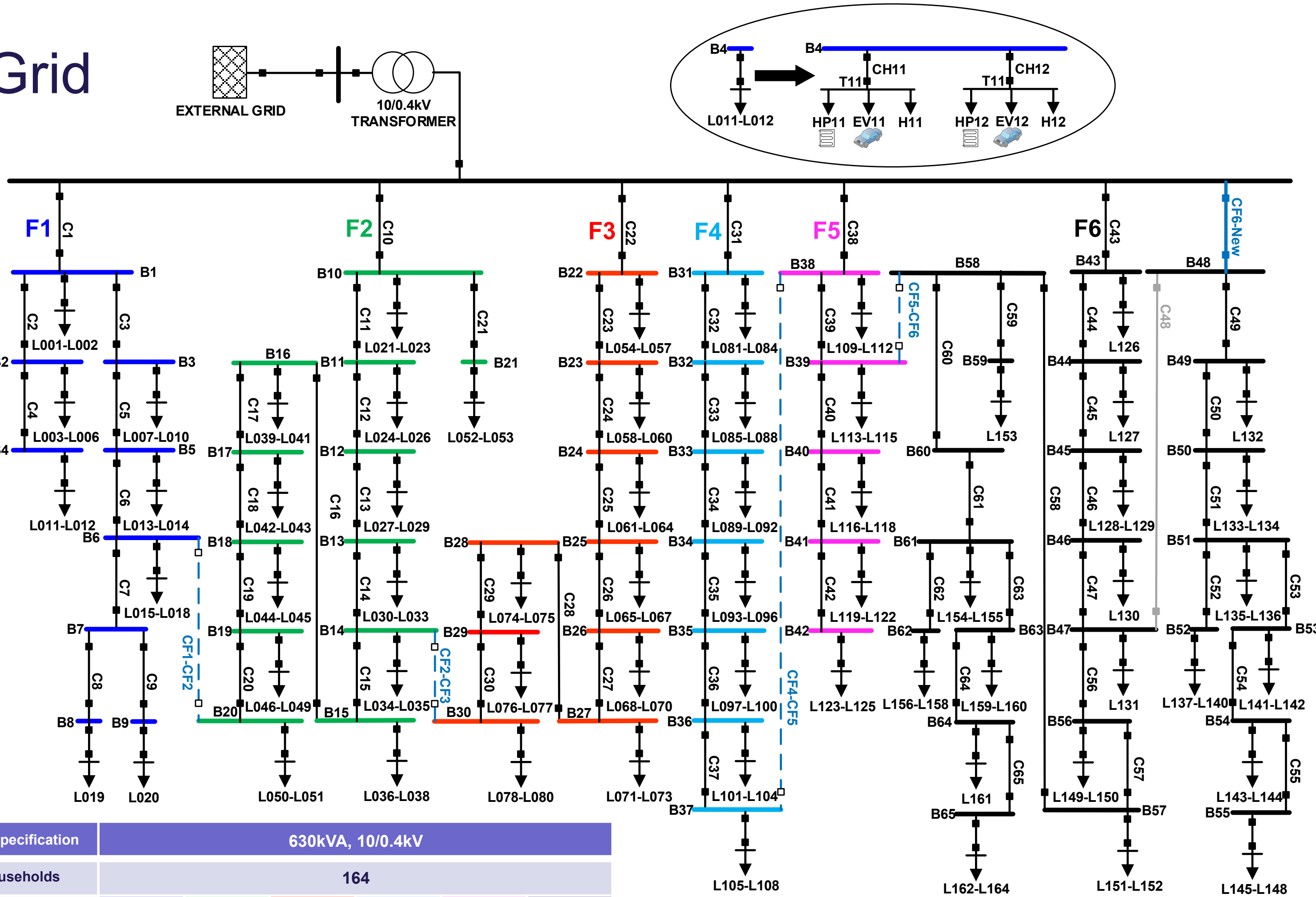
Introduction

- Flexibility benefits to the power system with the integration to the heating and transport impose a cost-effective solution towards zero carbon emission
- Electric vehichles (EVs) and heat pumps (HPs) offer potential flexibility in a peak shaping in demand and price profiles.
- In order to limit the need for grid reinforcement and energy management, demand response concept is increasing.
- The significant contribution of this study is to develop and implement adaptive ON/ OFF control strategies to EVs and HPs for real-time grid support with the use of an autonomous controller.
  - Supporting grid voltage and satisfying end-user need simultaneously.
  - The proposed control architecture is local and reduces the need for costly communication infrastructure to handle big data and control architecture.

System Architecture

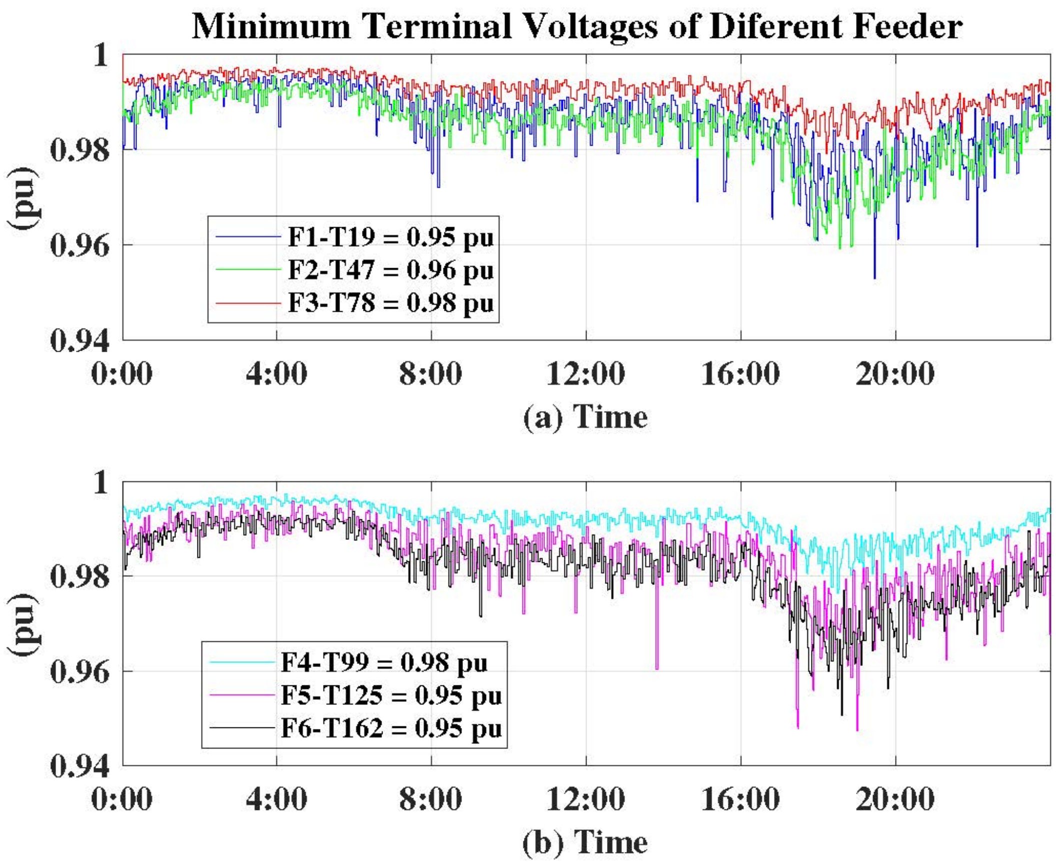


LV Grid



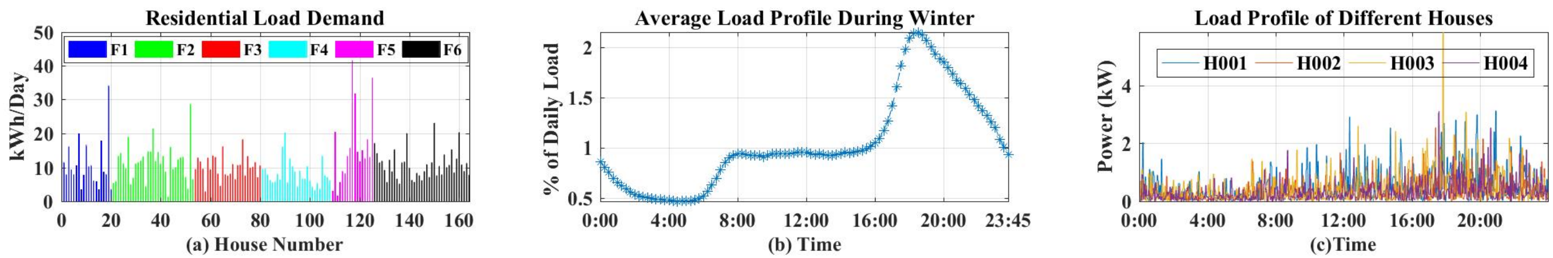
Transformer Specification	630kVA, 10/0.4kV					
Number of Households	164					
Feeder	F1	F2	F3	F4	F5	F6
Total HH load (kWh/day)	226	376	277	223	278	421
Number of houses	20	33	27	28	17	39
	Min (kWh/day)		Max (kWh/day)		Avg (kWh/day)	
Residential load	1.2		41		11	
Thermal load	8.3		88.2		34	

Grid Terminal Voltage with Only Residential Base Load

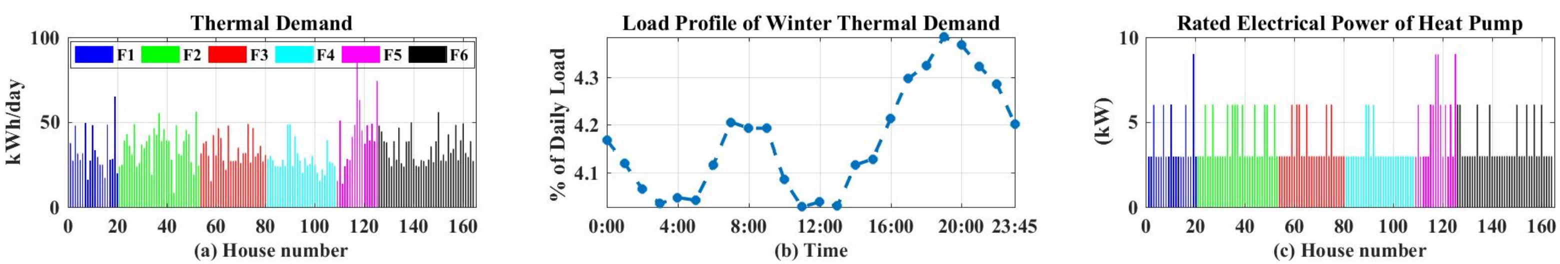


Residential and Thermal Load

Residential and Thermal Demands are Based on Actual Measurement from Residences in Denmark.

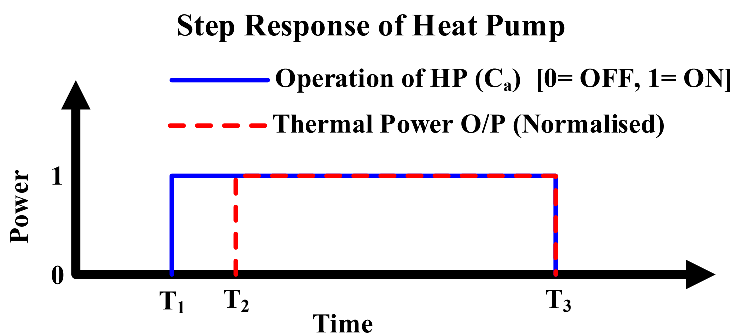


(a)Daily HH base load consumption (b) Load profile at secondary of transformer (c) Simulated daily residential load with noise

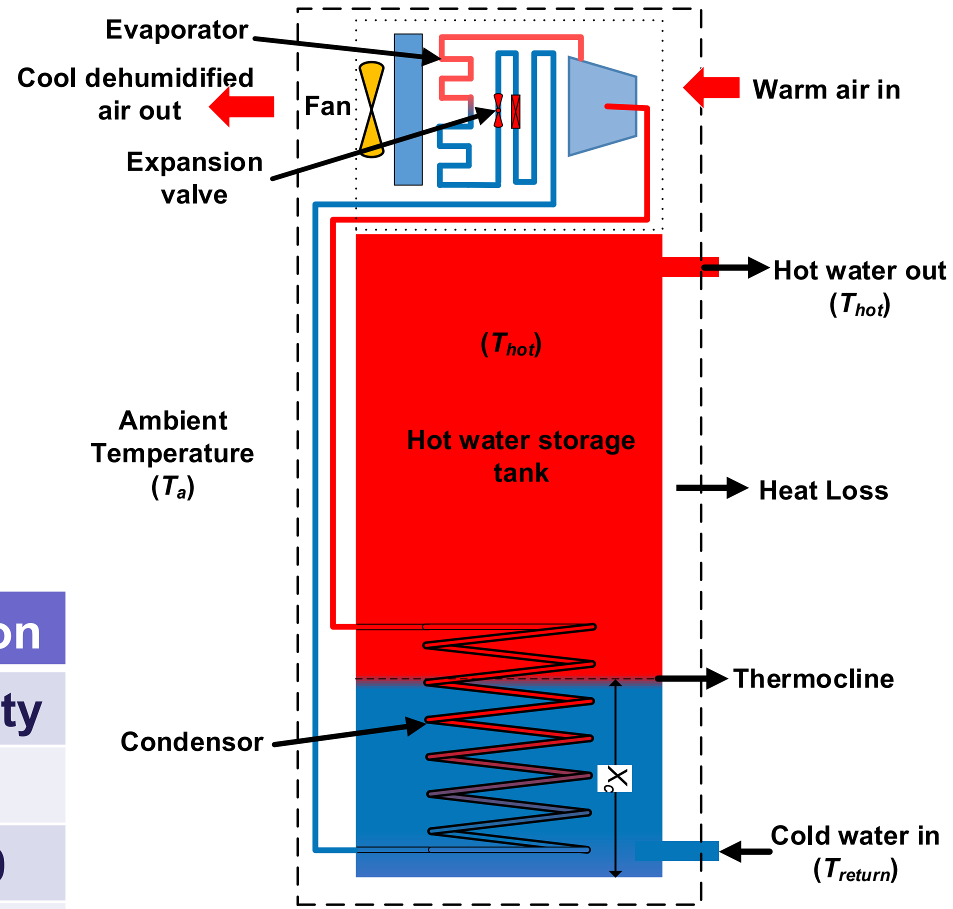


(a) Thermal consumption of 164 houses (b) Thermal load profile (c) Rated electrical power of HP

Heat Pump and Storage System



Step response of heat pump during turn-ON and turn-OFF

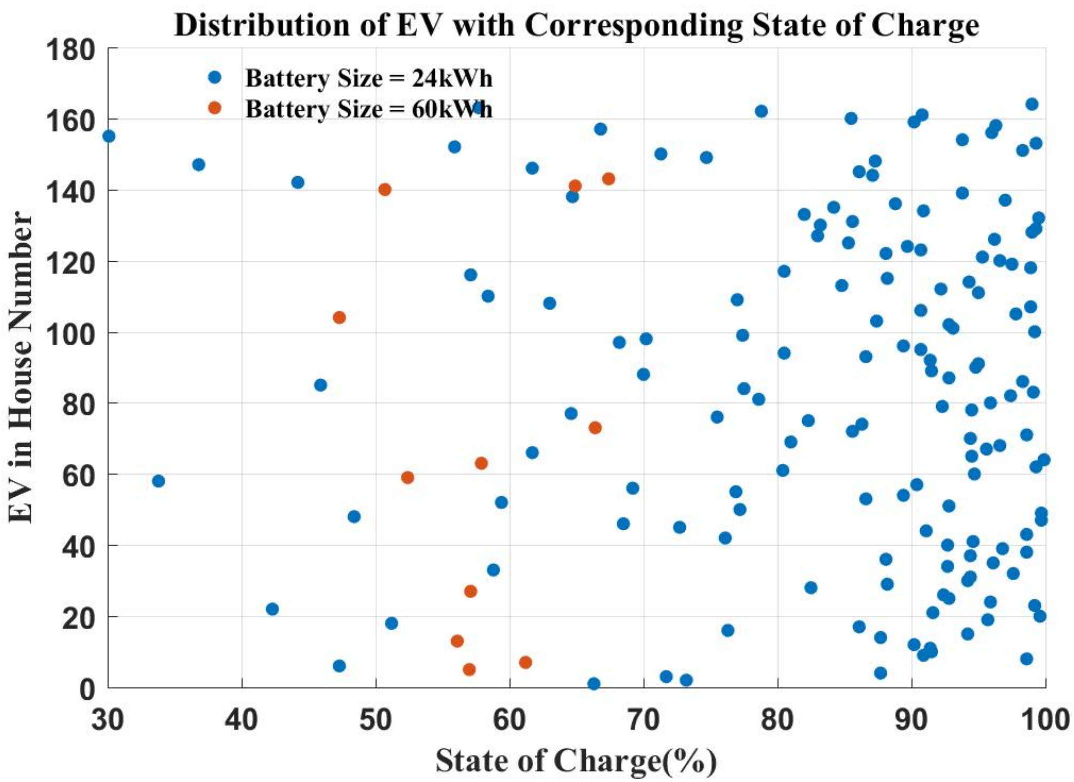


Heat pump and storage system

Control Parameter for HP Operation			
	Normal		Priority
	Max	Min	
T_{hot} (°C)	70	60	< 50
X_c (pu)	0.25	-	>0.4

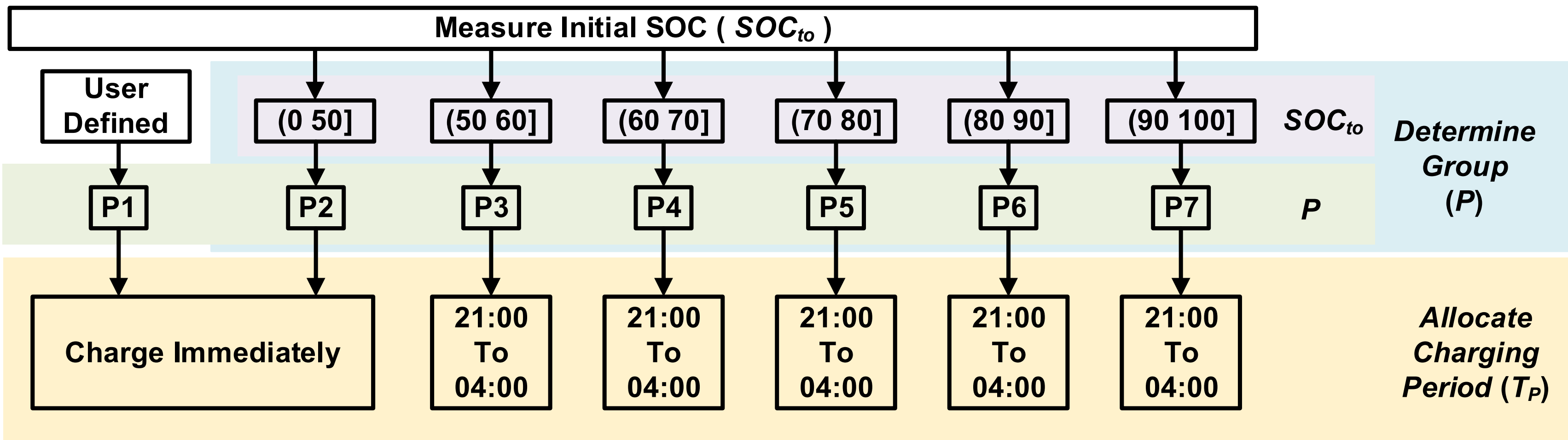
EVs' Distribution and State of Charge

Driving distance data from Danish national travel survey are used to generate SOC.



Charger capacity: 7.4kW for 24kWh Battery & 11kW for 60kWh Battery

EV Charging Management



In order to avoid grid congestion, charging time of EVs are distributed over the period of time (T_P) based on its different group

EV Charging Management

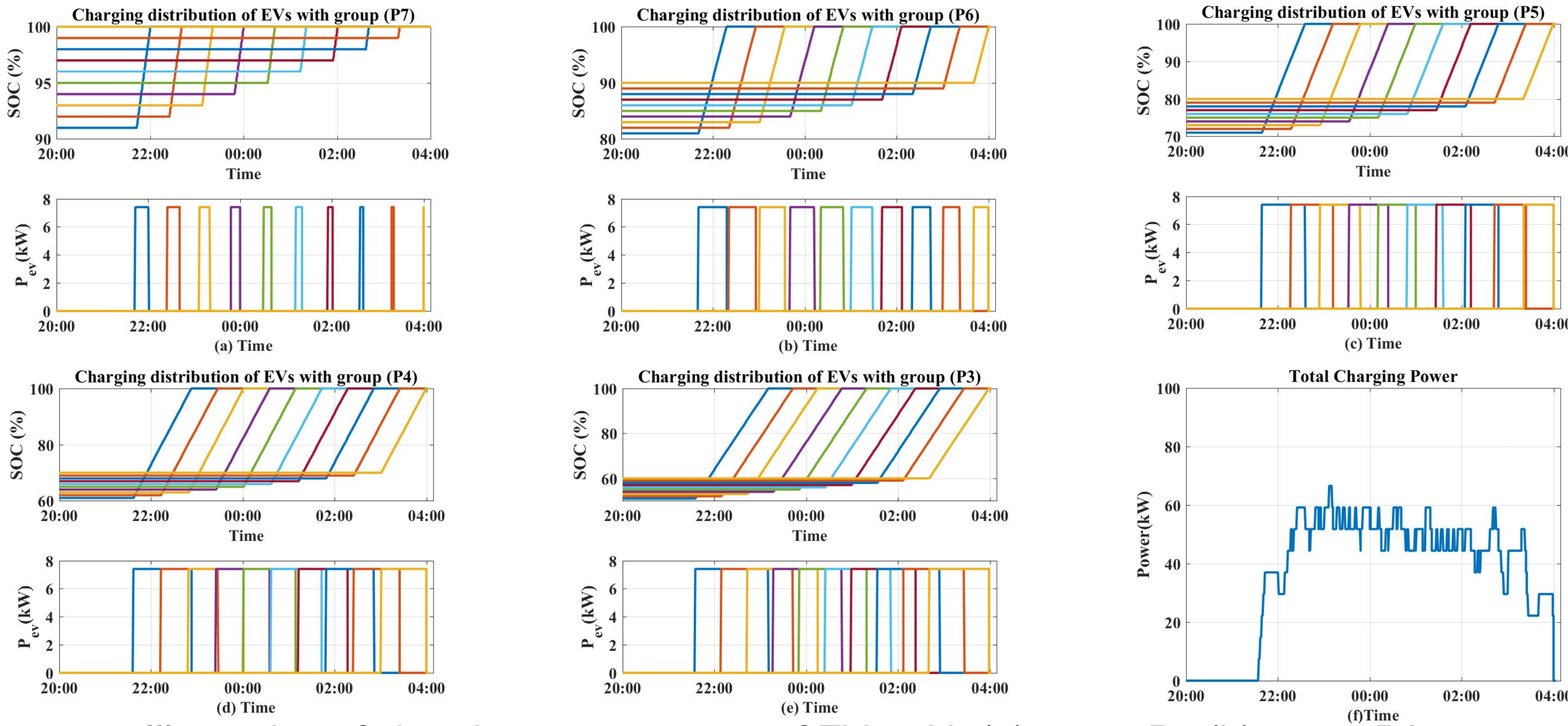
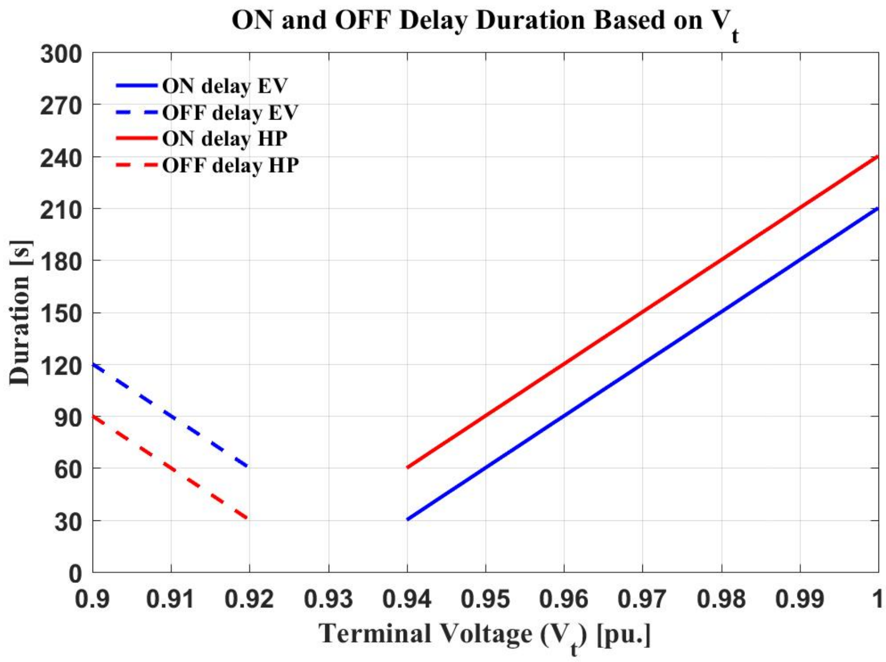


Illustration of charging management of EVs with (a) group P7 (b) group P6 (c) group P5 (d) group P4 (e) group P3 (e) Total Charging power

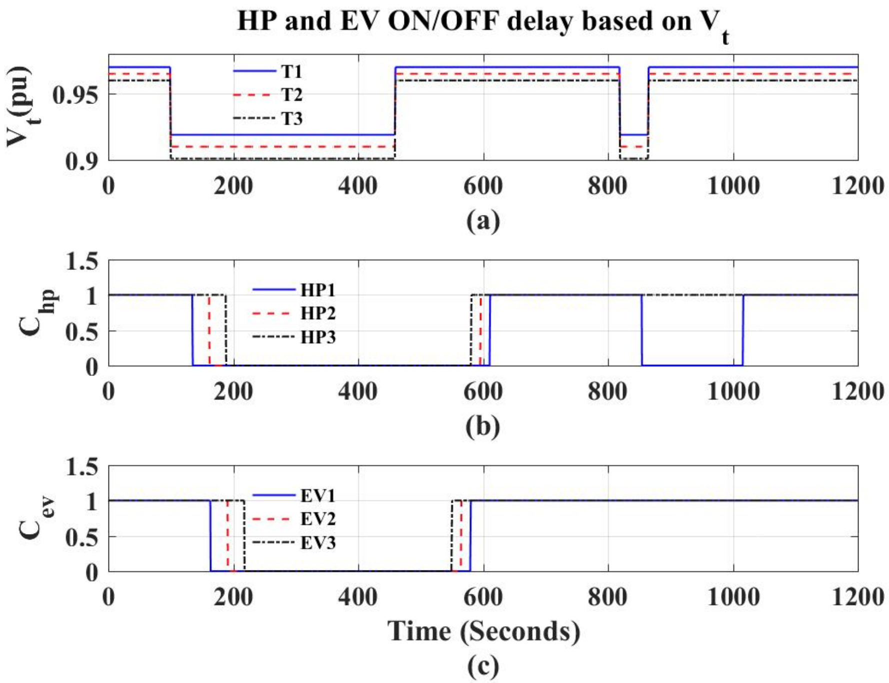
Coordination of EV and HP : Turn ON/OFF Delay Based on Terminal Voltage

- EVs have Priority over HPs
- EVs and HPs at far end of Feeder with lower terminal voltage has higher priority
- If $V_t \geq 0.94$pu, EVs charging and HPs operation are allowed until $V_t < 0.92$pu
- If $V_t < 0.94$pu, No other EVs and HPs that are in OFF state are allowed to charge or operate until $V_t \geq 0.96$pu (To avoid hunting effect)
- If V_t goes below 0.92pu for more than OFF delay time, EVs and HPs disconnects and reconnects only when V_t recovers to 0.96pu.
- If V_t goes below 0.9pu for more than 60 seconds, EVs and HPs in respective terminal attempts to operates only after 20min and 30min respectively.
- No ON/OFF delay for EVs and HPs with Priority



ON/OFF Coordination of EV and HP for Flexible Operation to Support Grid

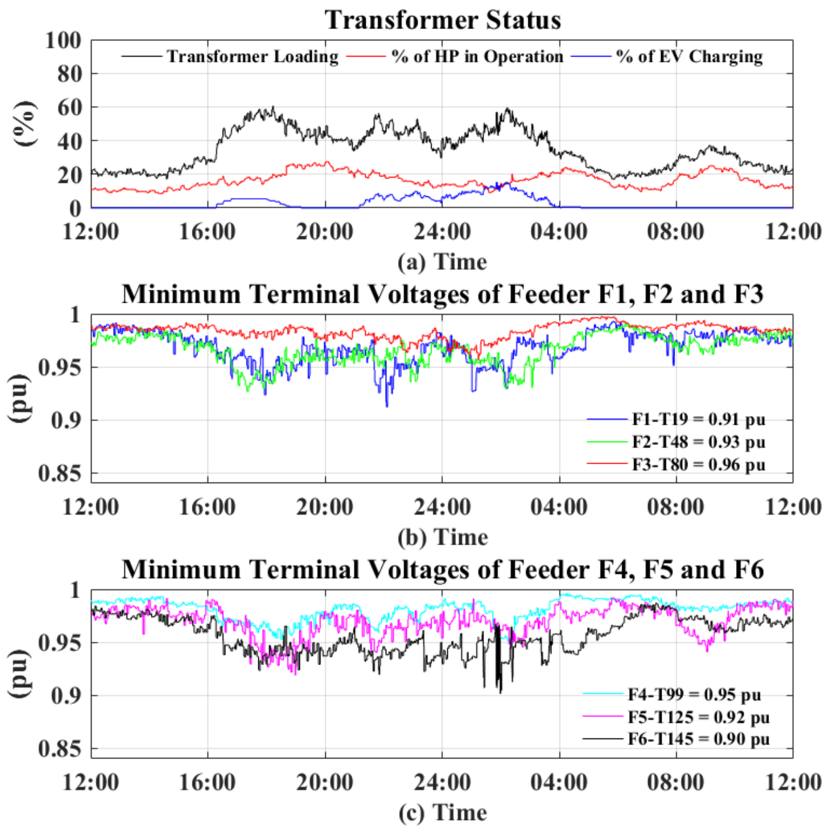
- EV1-HP1, EV2-HP2, and EV3-HP3 are connected to terminals T1, T2 and T3 respectively
- When V_t < 0.92pu, HPs and EVs disconnects consecutively as per OFF delay value



(a): terminal voltage (V_t), (b):C_{hp}, (c): C_{ev}

Results and Discussion

SUMMARY OF RESULT					
X_{mer} Loading	EV Charging	HP Operated	Max. Line Loading	Min T_{hot}	Max X_c
(%)	(%)	(%)	(%)	(°C)	(%)
61	15	28	62	51	30



Conclusion

- This work provides insights to the concept of the potential use of EVs and HPs as distributed flexible load in Denmark’s low voltage distribution network.

- The proposed control strategy plays an effective role in demand response to enhance flexibility in the operation of EVs and HPs while supporting grid voltage and satisfying end-user need simultaneously.