

### CREATORS

# Electric energy utilization in modern industrial environments







Sep. 6 - Sep. 9, 2022 | Nice, France



## Outline

- Facilities for electric energy production
- Facilities for energy storage
- Electric energy management •

Paper result of: CREATORS H2020 project https://www.creators4you.energy/

Speaker: Ivan Todorović https://www.typhoon-hil.com/

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\*Generally in use



ces	
	Non-Renewable Energy
ydro power	Microturbine Gas turbine Reciprocating engines
	Capacity Range
5-1500MW	25-500kW 5-400MW 10kW-10MW
	Efficiency
12%	20-32% 35-40% 30-45%
	Installation Cost
,535/kW ,05/kWh	0,05%/kWh $0,045$ %/kWh $0,045$ %/kWh
	GHG Emissions
o emission	Extremely high Extremely high



\*Generally in use in industrial facilities



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Percent of the 7× 10<sup>10</sup> liters (daily)



	Energy Sources	
	Renewable Energy	Non-Renewable Energy
<b>PV cell</b> Wind turbine	Fuel Cell     Tidal power     Geothermal     Hydro power	Microturbine Gas turbine
	Capacity Range	Capacity Range
<b>200-1500MW</b> 250-1500MW	<b>50kW-1MW 1.2-250MW 15-1500MW 15-1500MW</b>	25-500kW 5-400MW 10kV
	Efficiency	Efficiency
<b>15-40%</b> 35-45%	<b>40-60%</b> 80% 12% 12%	20-32% 35-40% 36
	Installation Cost	Installation Cost
1,3889\$/kW1,477\$/kW0,08\$/kWh0,06\$/kWh	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	0,05%/kWh $0,045$ %/kWh $0,04$
	GHG Emissions	GHG Emissions
<b>No emission</b> No emission	Average     No emission     Highly low     No emission	Extremely high Extremely high

### \*Novel energy sources for industrial applications





Tidal storage system Tidal energy systems Energy islands: Tidal + PV Offshore wind + PV Wave + PV Offshore wind + Wind

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Energy Sources	
Renewable Energy	Non-Renewable Energ
PV cell Wind turbine Fuel Cell Tidal power Geothermal Hydro power	Microturbine Gas turbine Reci
Capacity Range	Capacity Range
200-1500MW   250-1500MW   50kW-1MW   1.2-250MW   15-1500MW   15-1500MW	25-500kW 5-400MW 10kV
Efficiency	Efficiency
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Installation Cost	Installation Cost
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GHG Emissions	GHG Emissions
No emission     Average     No emission     Highly low     No emission	Extremely high Extremely high

\*Novel energy sources for industrial applications





## Facilities for energy storage\*

Energy Storage Technologies											
Electrochemical		Electromagnetic			Thermodynamic				Mechanical		
Batteries	Flow Batteries	Hydrogen	Electric	Magnetic		Pressure	Pressure + Heat	Heat		Gravity	Kinetic
Lead Acid NiCd	Vanadium ZnBr	Electrolyser + Fuel Cells	Supercaps	SMES		CAES	Adiabatic + CAES	Thermo - Electric		Pumped - Hydro	Flywheels
NiMh NaS	PSBr										
NaNiCl Li-Ion											
Metal Air PbSb Liquid											









## Facilities for energy storage\*

Energy Storage Technologies											
Electrochemical			Electromagnetic		Thermodynamic			Med	Mechanical		
Batteries	Flow Batteries	Hydrogen	Electric	Magnetic	Pressure	Pressure + Heat	Heat	Gravity	Kinetic		
Lead Acid NiCd	Vanadium ZnBr	Electrolyser + Fuel Cells	Supercaps	SMES	CAES	Adiabatic + CAES	Thermo - Electric	Pumped - Hydro	Flywheels		
NiMh NaS	PSBr										
NaNiCl											
Li-Ion Metal Air											
PbSb Liquid											

\*Generally in use in industrial facilities

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## Facilities for energy storage\*



\*Novel energy storage systems for industrial applications



Small-scale pumped-hydro systems (Energy hill) Other gravity-based storage systems: Lagoon storage Deep shaft Artificial basin

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## Facilities for energy storage

Applications of ESS	Minimum Response Time	Minimum Discharge Duration
	Generation	
Uninterrupted and stable power flow	S	10 min – 2 h
Peak shaving	min – h	s – 10 h
Black-start	s – min	1 h – 6 h
Mobile applications	ms — s	s – h
	Transmission	
Postponement of infrastructure upgrades	min	1 h – 6 h
Voltage regulation	ms — s	6 min – 1 h
	Distribution and end-user services	
Power quality	< 5 ms	ms – 1.2 min
Reliability	5 ms – s	5 min – 5 h
Voltage support	< 5 ms	15 min
Postponement of infrastructure upgrades	min	2 h – 8 h
Ride-through support	< 5 ms	10 s – 15 min
Transportation applications	ms — s	s – h



## Facilities for energy storage









### Energy Management Schemes

### Classical Optimization Methods

Dynamic programming Linear programming Nonlinear programming Mixed-integer linear programming Mixed-integer nonlinear programming Mixed integer quadratic programming Adaptive multi-clustering algorithm Stochastic programming Rule-based algorithm

### Heuristic and Metaheuristic Methods

Genetic algorithm Particle swarm optimization algorithm Differential evolution algorithm Adaptive differential evolution algorithm Whale optimization algorithm Grey wolf optimization algorithm Evolutionary algorithm Non-dominated sorting genetic algorithm Artificial bee colony Pareto concavity elimination transformation •••



### Intelligent Methods

Neural networks-based approaches Fuzzy-logic controllers-based algorithms Model predictive algorithms Multi-agent systems schemes

### Emerging Methods

Game theory-based Deep learning-based Deep reinforcement-learning-based

### Energy Management Schemes

### Centralized

Equivalent consumption minimization strategy Model predictive control Sequential function method Hierarchical control Sensitivity function method Recursive searching algorithm Artificial intelligence algorithm

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### Distributed

Multiagent systems Distributed model predictive control Alternating direction method of multipliers

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### **Optimization methods goals\***

Optimal storage management	Lo
Demand response program Vehicle-to-grid system (V2G)	Postponer
Cost minimization Energy scheduling Operating time	Mair Volte
Reliability of operation Losses minimization	Po
Generate energy with lower emissions Uninterrupted power flows Stable power flows Peak shaving	Frequ Ride- Transpor



### bad shedding Black-start

- ment of infrastructure upgrades
- ntenance costs
- age regulation
- ower quality
- Reliability

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- oltage support
- Jency regulation
- -through support
- rtation applications



\*With even more constraints...

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- Scalability
- Applicability
- Standardization •
- Development •
- Testing •

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Implementability



- Scalability
- Applicability
- Standardization
- Development •
- Testing •

Scientific problem

### Technical problem

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# Thank you!

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This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 957815









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