ENERGY STORAGE SYSTEMS FOR SOLAR PV INTEGRATION

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FINAL YEAR PROJECT PRESENTATION

ENGINEERING TECHNOLOGY
PROJECT A - ENG40007

BACKGROUND

GLOBAL PUSH FOR RENEWABLES

GRID STRAIN FROM HIGH SOLAR PENETRATION

LIMITED RESOURCES AND HIGH COSTS

INTERMITTENT AND UNRELIABLE NATURE OF SOLAR

PROBLEM STATEMENT

DEMAND-SUPPLY IMBALANCE

VOLTAGE SURGE

FREQUENCY INSTABILITY

EXISTING SOLUTIONS AND LIMITATIONS

- GOVERNMENT INCENTIVES FOR LI-ION BATTERY ADOPTION
- HIGH CAPITAL AND MAINTENANCE COSTS
- RESOURCE SCARCITY (E.G., LITHIUM, COBALT)
- ENVIRONMENTAL IMPACT (MINING, DISPOSAL)
- UNDERUTILISATION OF ALTERNATIVE STORAGE TECHNOLOGIES

Aims and Objectives

Analyse	Analyse the impact of high solar penetration on grid performance
Determine	Determine the most suitable hybrid energy storage system for household integration
Design	Design an ESS integrated PV system
Simulate and Validate	Simulate and Validate the performance of proposed system
Minimise	Minimise and eventually eliminate negative impacts of high solar penetration on grid stability

Overview of storage devices used in power industries

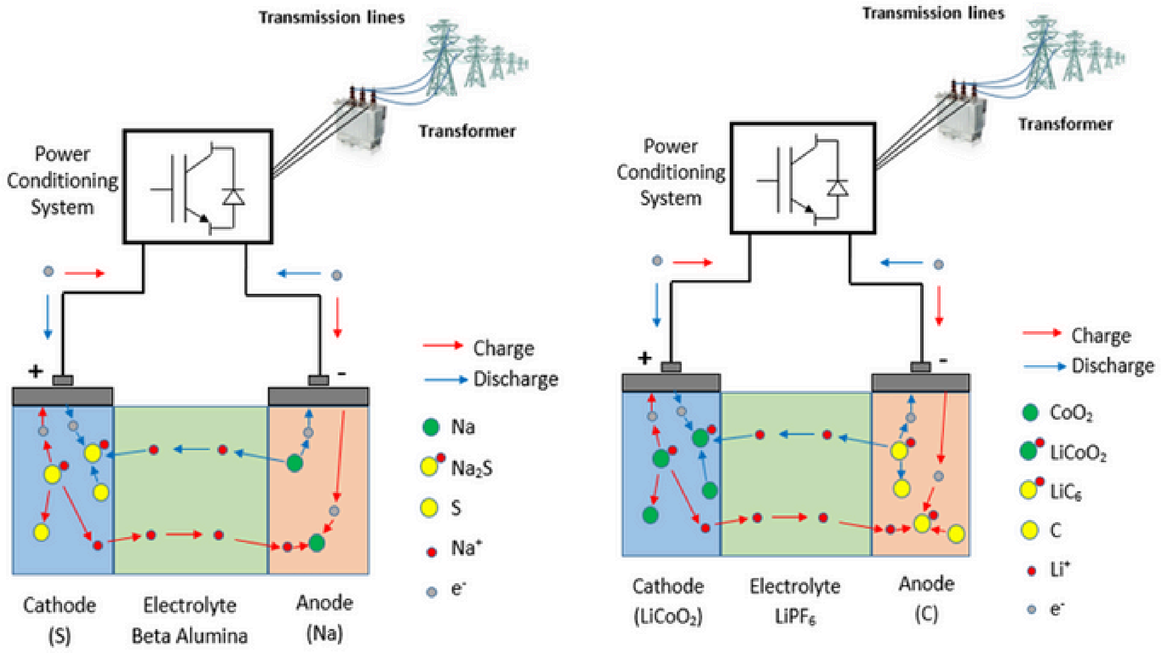
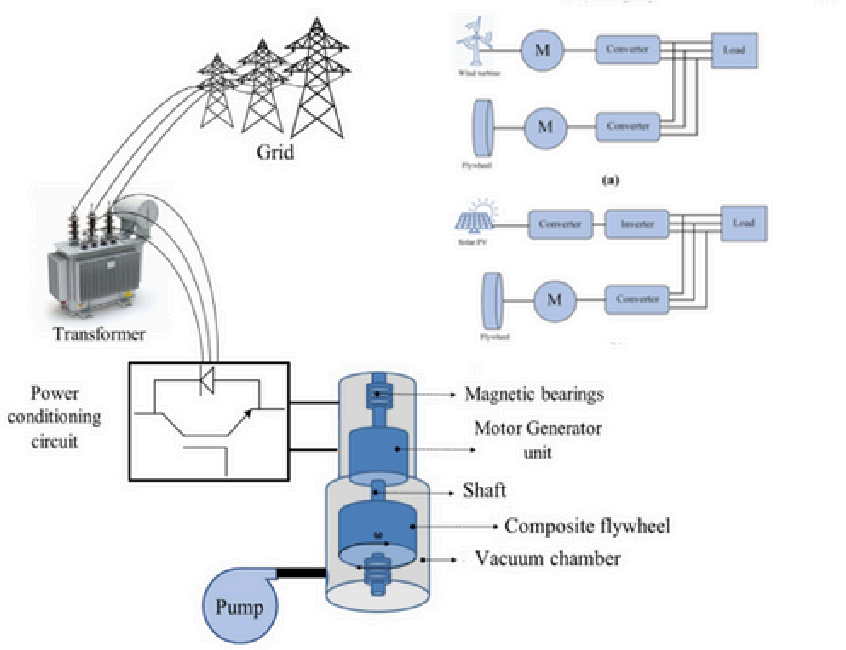


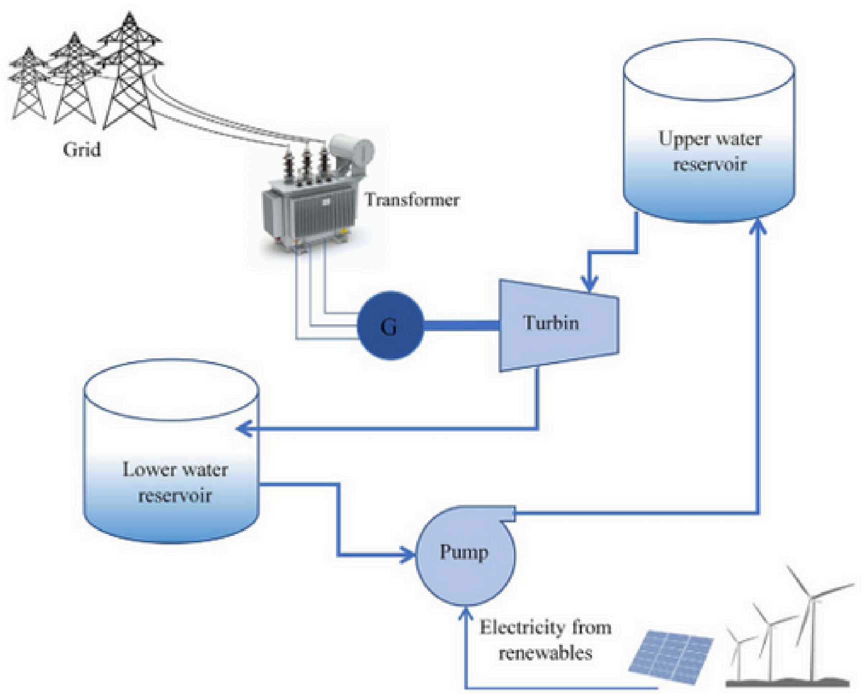
Figure 9: Schematic diagram of Na-S battery energy storage system

Figure 10: Schematic diagram of Li-ion battery energy storage system

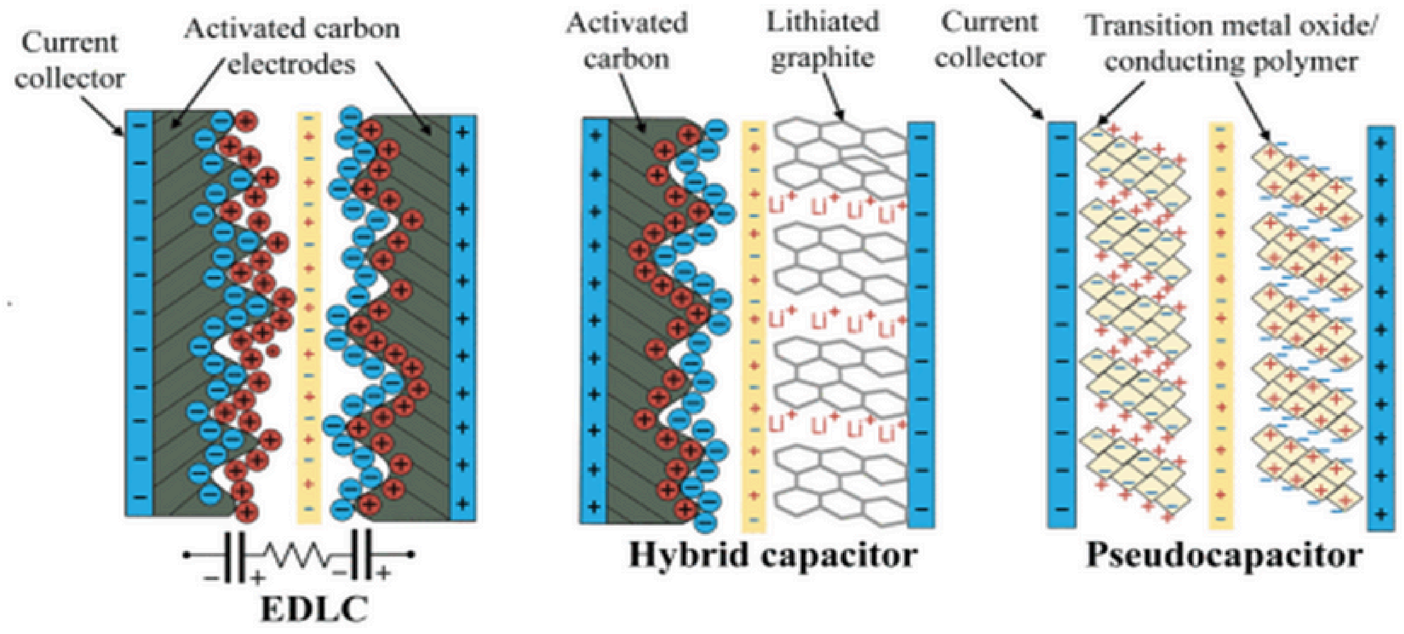
1. Na-s Battery Storage and Li-ion battery storage system [1]



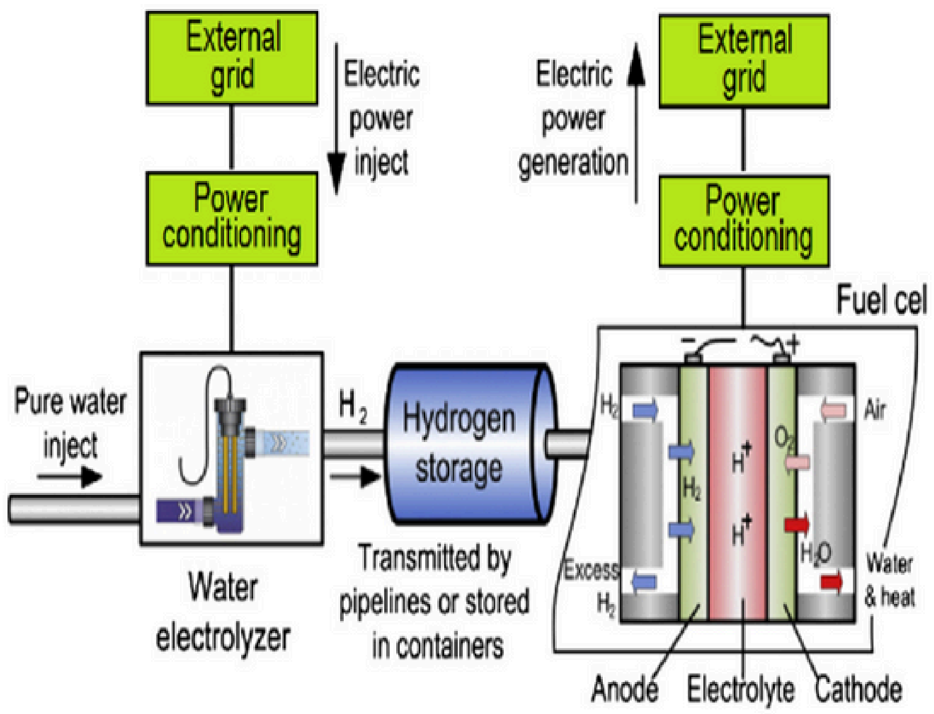
2. Flywheel Energy Storage [4]



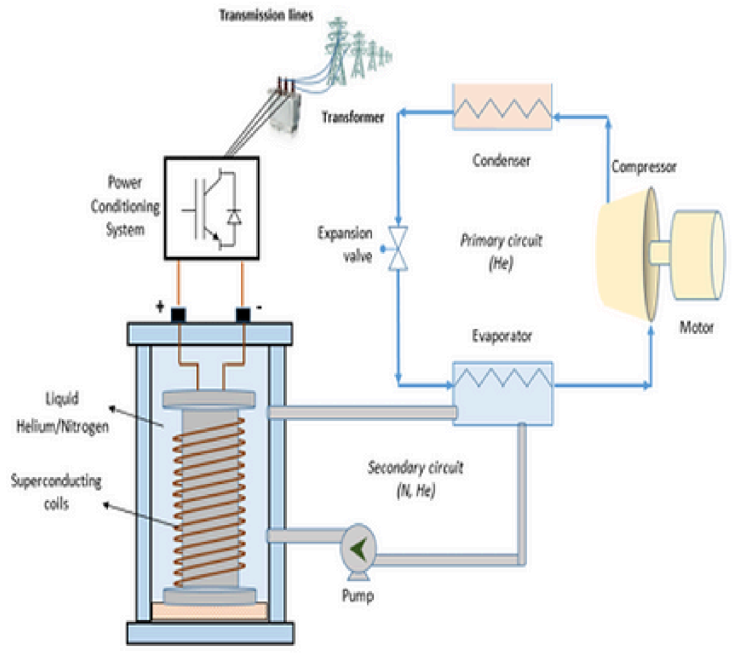
3. Pumped Hydro Energy Storage [4]



4. Supercapacitors [5]



5. Hydrogen Storage and fuel cell [3]

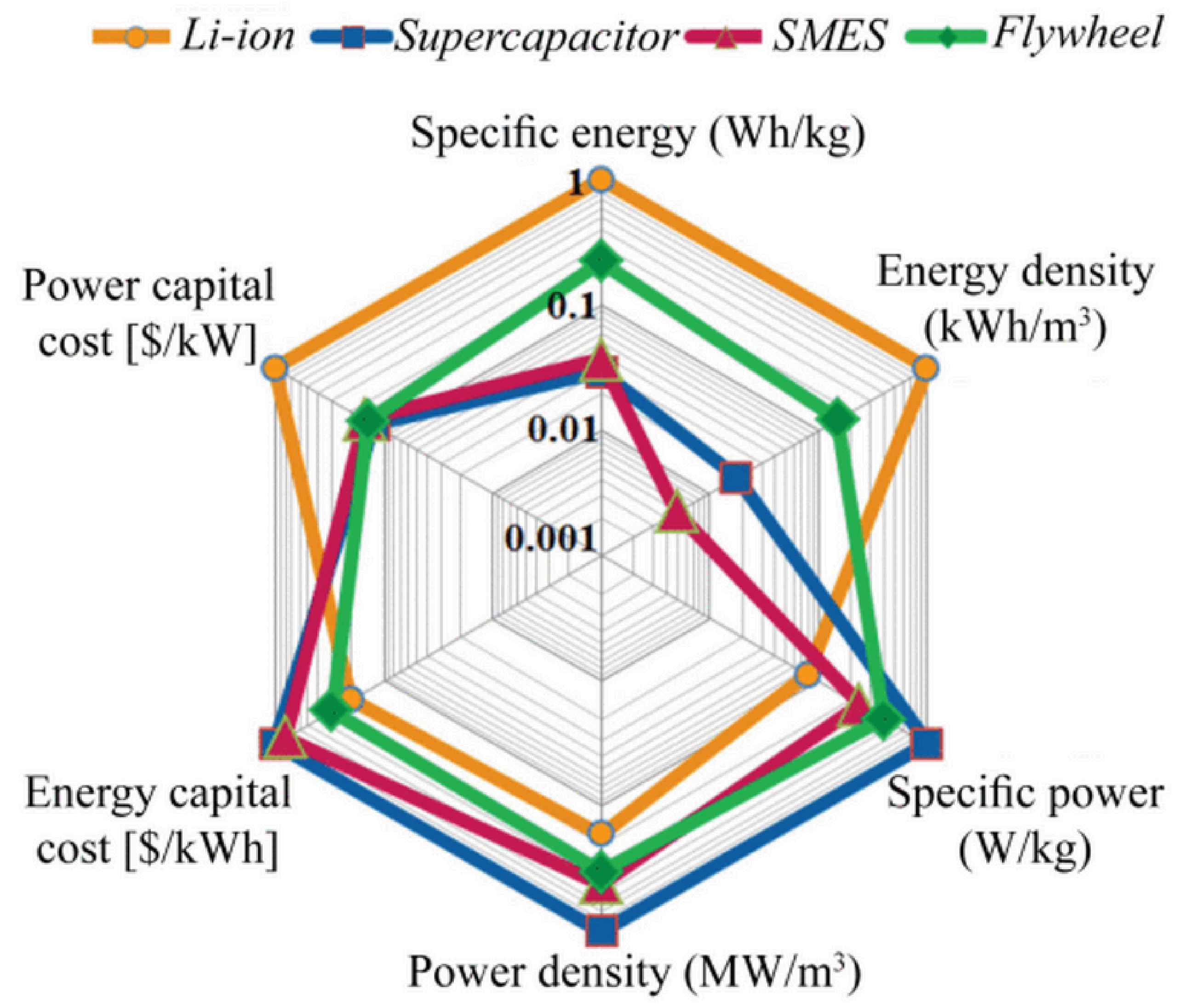


6. Superconducting Magnetic Energy storage (SMES)[1]

Comparison of Storage Devices

Energy storage	Specific power (maximum) (W/kg)	Specific energy (Wh/kg)	Life cycle	Temperature range
Li-ion battery	3 000	200	500 – 1 000	0 to 60 °C
Lead-acid battery	250	100	500 – 1000	0 to 40 °C
Symmetrical supercapacitor	10 000	4 – 10	500 000 – 1 000 000	−40 to 60 °C
Hybrid supercapacitor	5 000	7 – 12	40 000 – 50 000	−20 to 60 °C
Capabattery	4 000	20 – 60	15 000 – 20 000	−20 to 50 °C

Table 1. Comparison storage of devices [2]



1. Comparision storage of devices [2]

Table 1.Comparison of different energy storage technologies.

	supercap	SMES	flywheel	lead-acid	lithium-ion	NaS	redox-flow	hydrogen	pumped hydro	CAES
energy density in Wh/l	2-10	0,5-10	80-200	50-100	200-350	150-250	20-70	750/250bar 2400/liquid	0,27-1,5	3-6
installation costs in €/kW	150-200	high	300	150-200	150-200	150-200	1000-1500	1500-2000	500-1000	700-1000
installation costs in €/kWh	10000-20000	high	1000	100-250	300-800	500-700	300-500	0,3-0,6	5-20	40-80
reaction time	<10ms	1-10ms	>10ms	3-5ms	3-5ms	3-5ms	>1s	10min	>3min	3-10min
self-discharge rate	up to 25% in first 48h	10-15 %/day	5-15 %/h	0,1-0,4 %/day	5 %/month	10 %/day	0,1-0,4 %/day	0,003-0,03 %/day	0,005-0,02 %/day	0,5-1 %/day
cycle life-time	>1Mill.	>1Mill.	>1Mill.	500-2000	2000-7000	5000-10000	>10000	>5000		
life-time in years	15	20	15	5-15	5-20	15-20	10-15	20	80	ca. 25
system efficiency in %	77-83	80-90	80-95	70-75	80-85	68-75	70-80	34-40	75-82	60-70
short-term (<1min)	XXX	XXX	XXX		X		X			
mid-term (>1min,<2d)			X	XXX	XXX	XX	XX	X	XX	XX
long-term (>2d)				X		X	XX	XXX	XXX	XX

Table 2. Comparison storage of devices [6]

Hybrid System Example / Integration Possibilities

- Li-ion battery + Supercapacitor
- Hydrogen + Li-ion battery
- Flow battery + Li-ion battery
- Lead-acid + Supercapacitor
- Flywheel + Battery

Research Gaps

Lack of research into hybrid energy storage systems

Lack of simulation/testing under high solar penetration

Integration and control strategy challenges

METHODOLOGY

01 Research: Investigated the characteristics, capabilities, and limitations of various energy storage technologies (ESS).

02 Selection criteria: Establish ideal performance metrics for ESS.

03 Theoretical Comparative Analysis: Evaluate and compare ESS technologies based on selection criteria, strictly theory based.

04 Selection: Identify the most suitable ESS and hybrid combinations for solar PV integration.

05 Incorporation of PSSE: Incorporate Python coding and .dyr files created to automate a PSSE microgrid design and simulate ESS data.

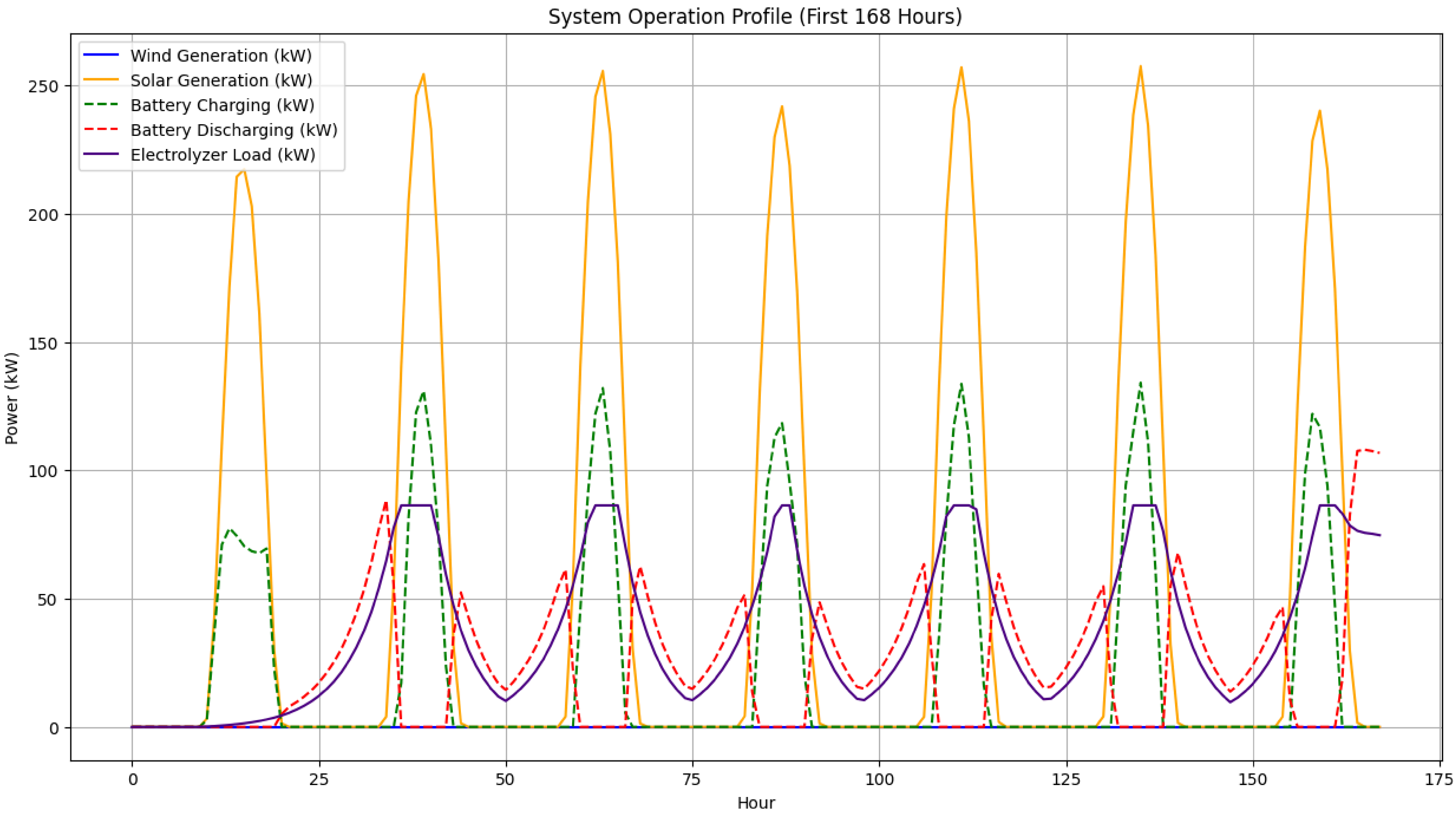
06 Simulation and Testing: Simulate the performance of selected ESS setups under real world conditions.

07 Practical Comparative Analysis: Evaluate and compare ESS technologies, based on newfound simulation results, and compare to past findings.

08 Cost Analysis and Final Decision: Completing LCOE reports, based on all available and discovered factors, leads to a conclusion about which ESS is most optimal in a high solar-penetration power distribution network.

THEORETICAL SIMULATION

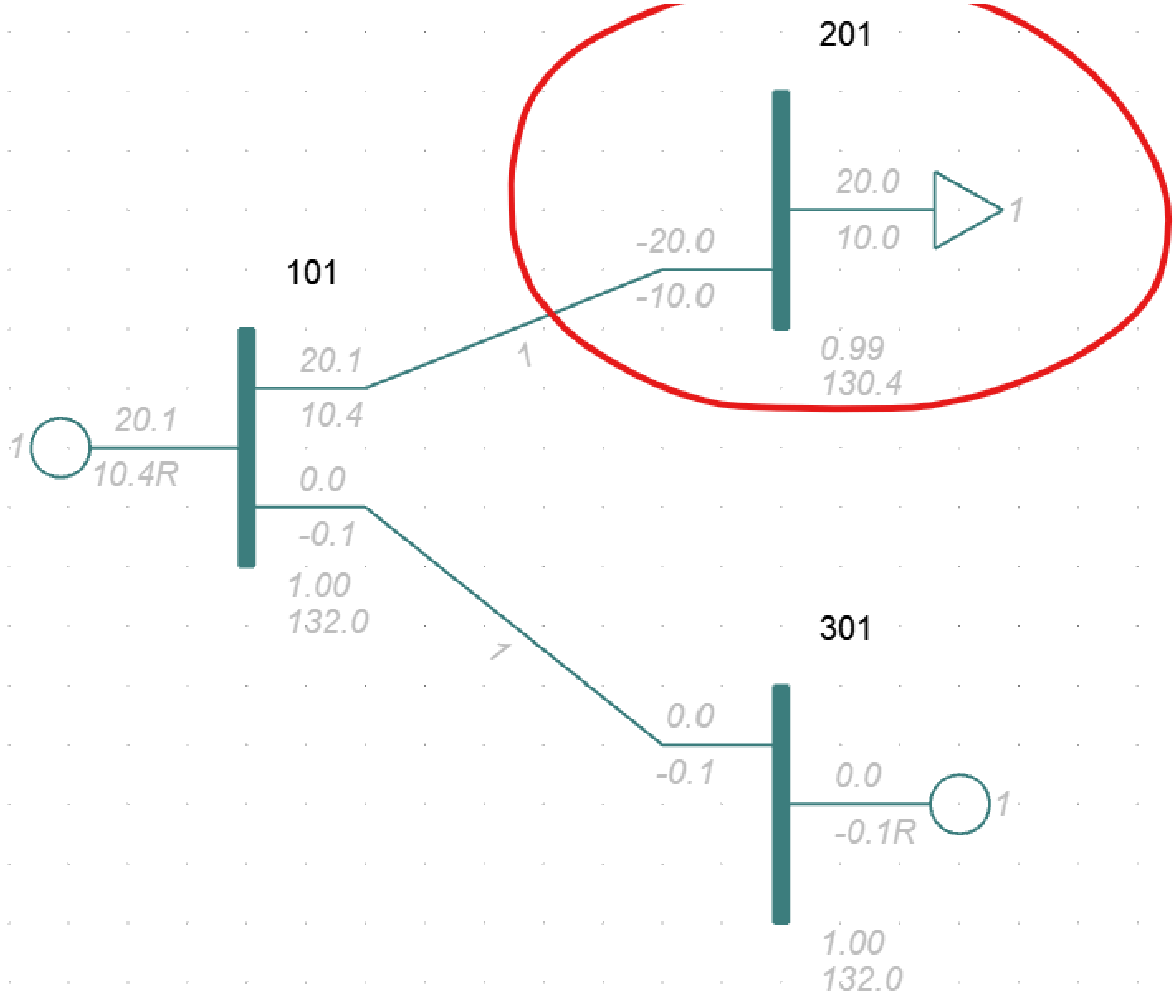
BESS FUNDAMENTALS



CONCEPTUAL SIMULATION

COMPLETED ON PSSE (TO DATE)

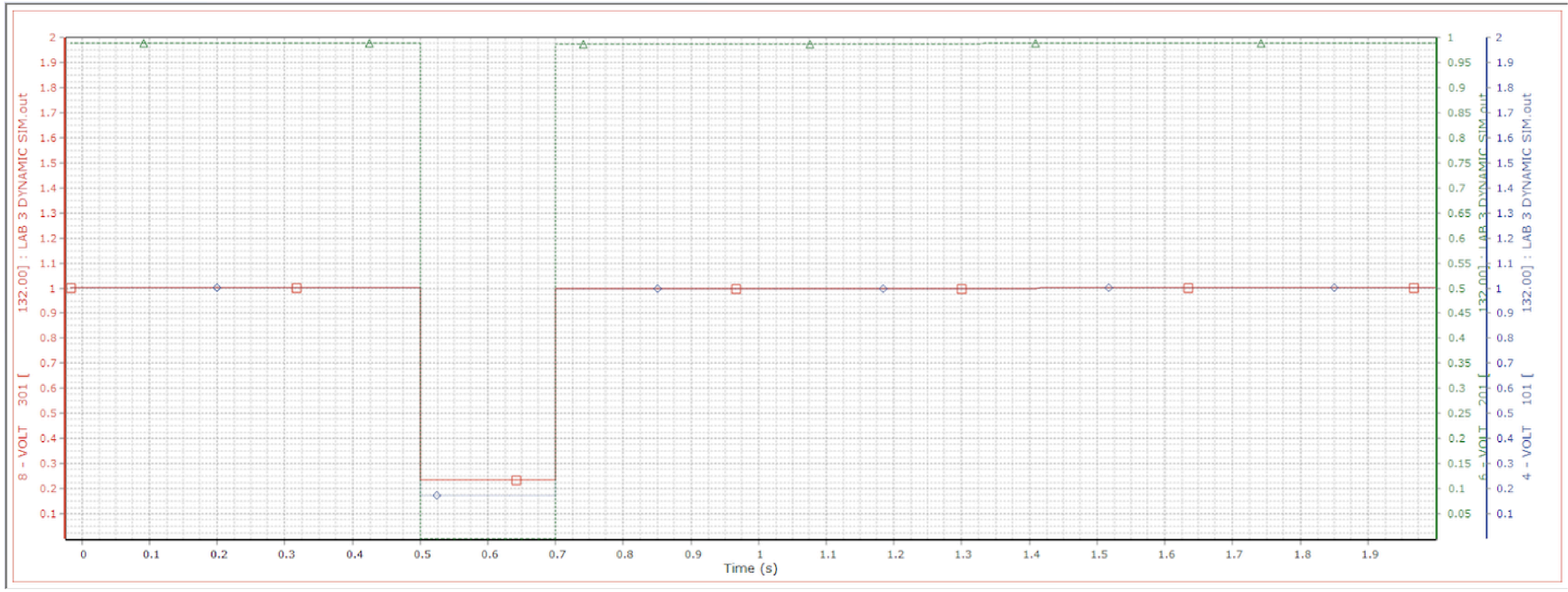
SIMULATION SCHEMATIC:

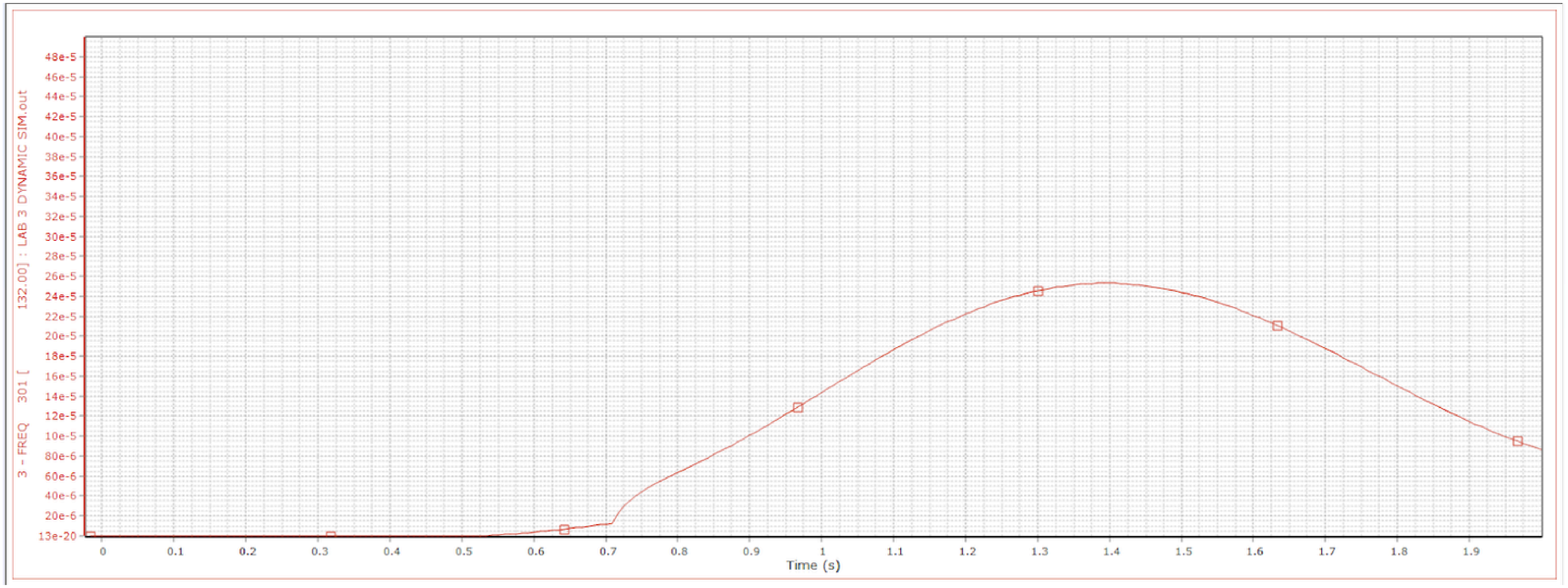


CONCEPTUAL SIMULATION

COMPLETED ON PSSE (TO DATE)

DYNAMIC DATA SIMULATION + FAULT DATA ANALYSIS OUTPUTS:





CONCEPTUAL SIMULATION

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DYNAMIC DATA
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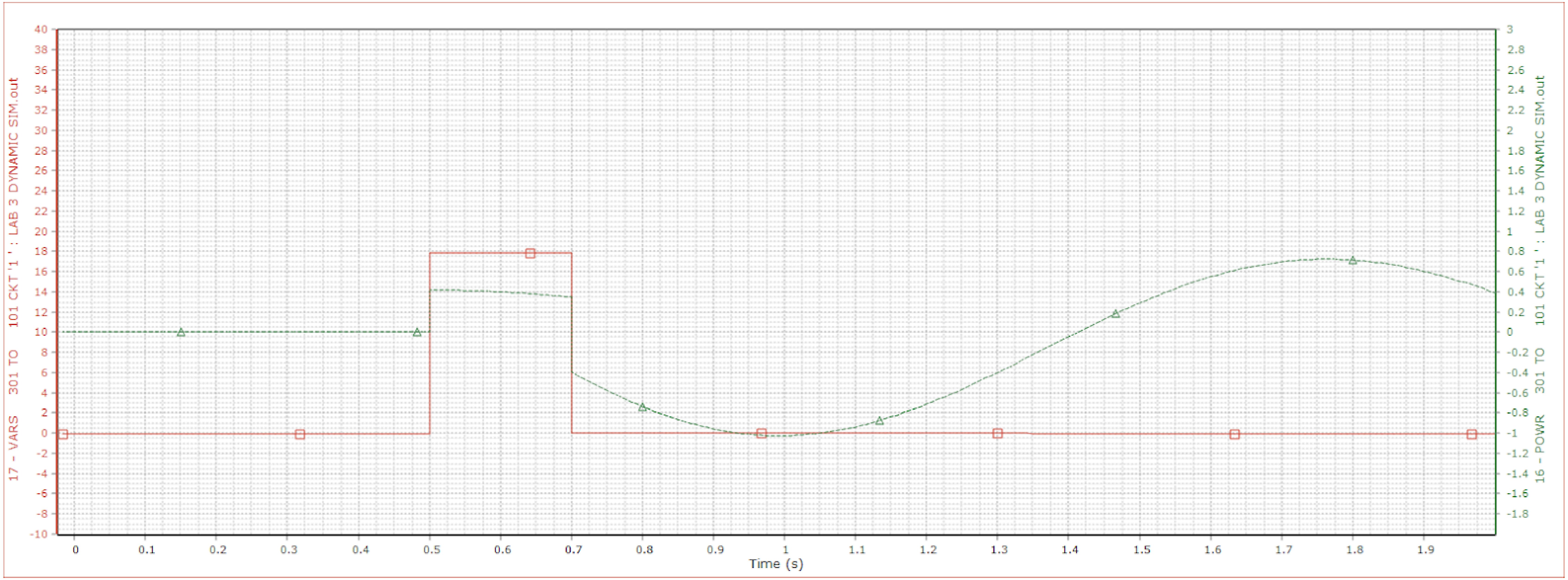


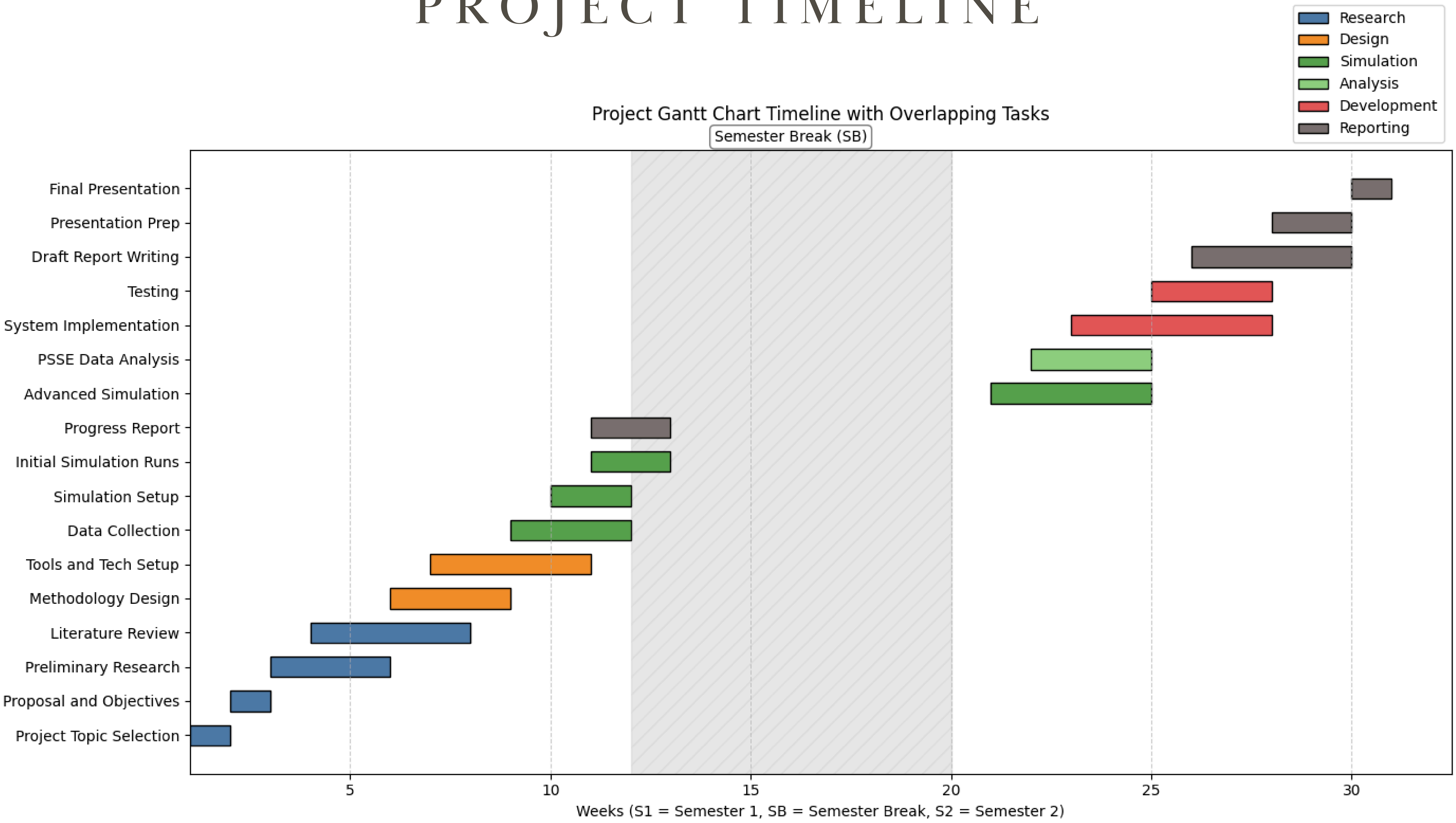
EXPECTED OUTCOMES AND DELIVERABLES

PSSE

Google Collaborate

AutoCAD

PROJECT TIMELINE



Thank You

References

•[1] X. Luo, J. Wang, M. Dooner, and J. Clarke, "A review of energy storage types, applications and recent developments," *Journal of Energy Storage*, vol. 1, pp. 22–31, 2015

•[2] X. Luo, J. Wang, M. Dooner, and J. Clarke, "Overview of current development in electrical energy storage technologies and the application potential in power system operation," *Renewable and Sustainable Energy Reviews*, vol. 33, pp. 177–213, Oct. 2014.

•[3] J. Kleperis *et al.*, “Energy storage solutions for small and medium-sized self-sufficient alternative energy objects,” *ResearchGate*, 2016.

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•[6] Bocklisch, T 2015, ‘Hybrid Energy Storage Systems for Renewable Energy Applications’, Energy Procedia, vol. 73, pp. 103–111