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Laboratory study on the Synchronization Process in Ship Power Systems under Unbalanced Conditions

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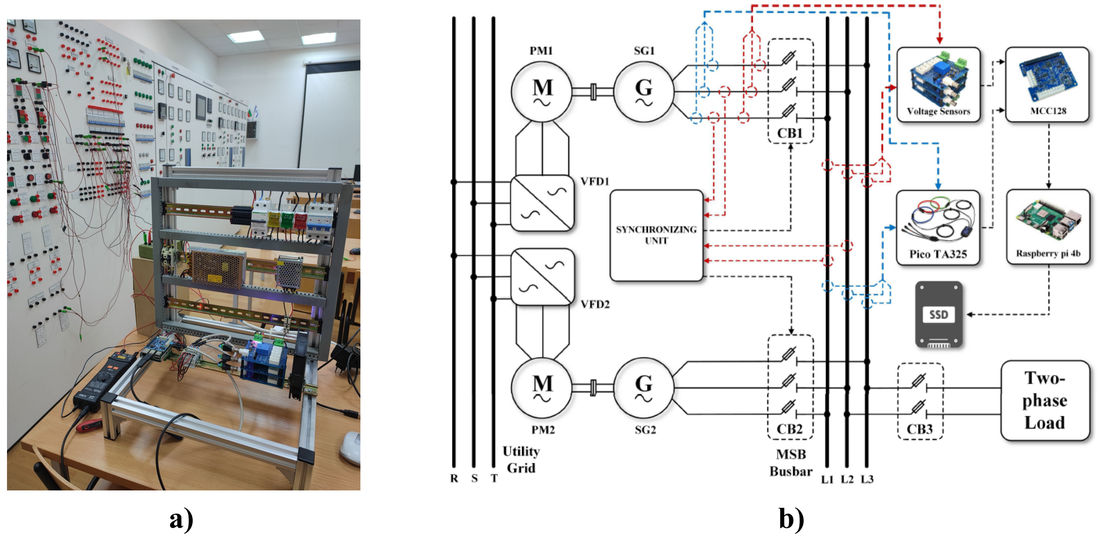
GOAL OF THE STUDY

The study investigates how load unbalance affects the synchronization of shipboard generators. A laboratory setup with two generators and a two-phase load was developed to emulate ship power conditions. Experimental analyses under balanced and unbalanced scenarios provide insights to improve synchronizer performance and ensure reliable parallel operation in marine power systems.

METHODOLOGY OF THE INVESTIGATION

A laboratory-scale setup was used to emulate a shipboard power system with controlled load unbalance. The experimental procedure focused on recording voltage and current waveforms during three synchronization stages—before, during, and after generator paralleling. Data were processed to extract RMS values, sequence components, and unbalance factors, allowing detailed evaluation of synchronizer performance and power quality variations throughout the process.

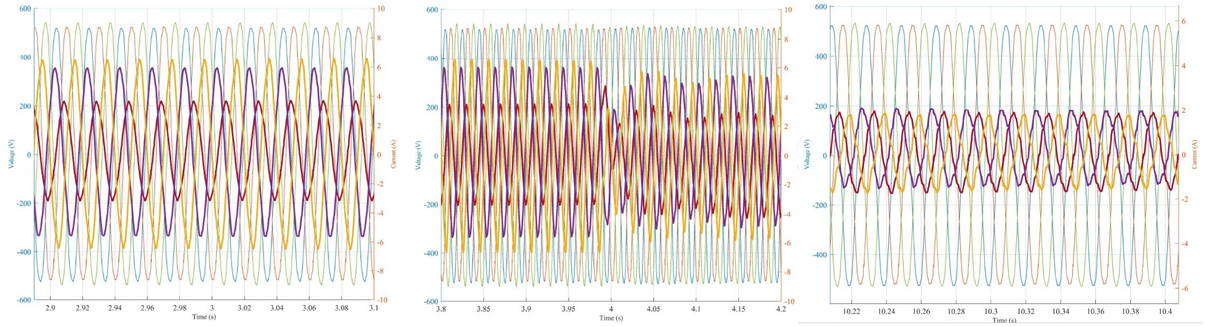


a) b)

Fig. 1. Photo of the experimental setup (a) and block diagram of the experimental setup (b)

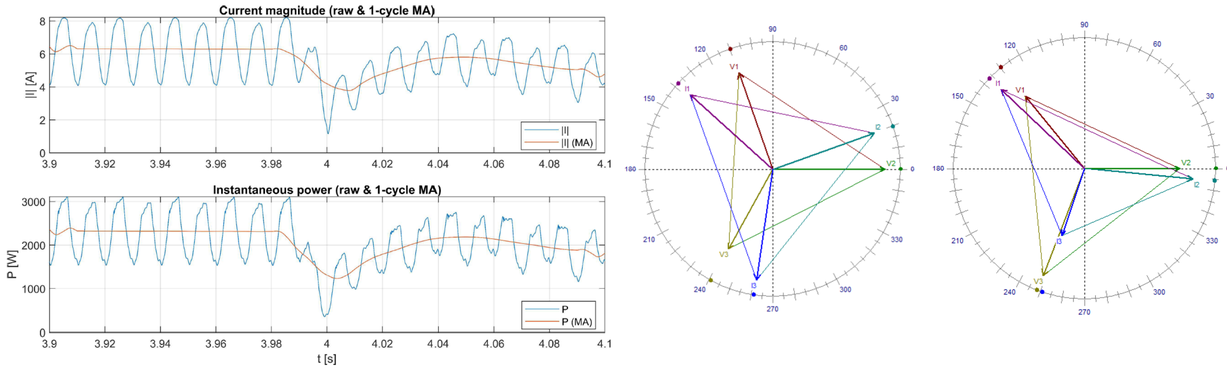
MAIN RESULTS FROM THE STUDY

Under unbalanced loading, voltage asymmetry remained low (VUF < 2.2 %), while current asymmetry was pronounced (IUF up to 32.6 %). The synchronization transient revealed a lightly damped 10.5 Hz oscillation associated with electromechanical coupling. The synchronizer maintained stable operation, and post-synchronization conditions confirmed acceptable voltage quality but significant negative-sequence currents stressing the generators.



a) b) c)

Fig. 2. SG-2 pre (a), during (b), and post (c) synchronization three-phase voltages and currents



a) b) c)

Fig. 3. SG-1 current magnitude and instantaneous power: raw vs 1-cycle MA (a), pre (b) and post synchronization voltage and current phasors

CONCLUSIONS

The study confirmed that synchronization under unbalanced conditions is feasible but leads to considerable current asymmetry and low-frequency oscillations. The results highlight the importance of monitoring negative-sequence currents and improving synchronizer control strategies. The developed platform serves as a practical tool for future research on adaptive synchronization and compensation techniques in shipboard power systems.

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