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Repurposing Inactive Oil and Gas Wells for Energy Storage: Maximizing the Potential via Optimal Drivetrain Control

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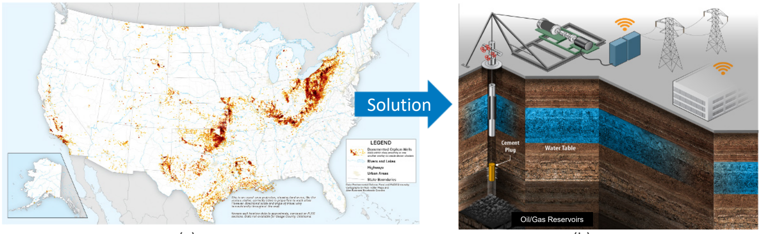
1. Background

- Traditional energy storage systems are challenged by **carbon-intense construction, high cost** of colocating renewable energy sources, and **low round-trip efficiency** (typically 70%).
- The United States has several **idle** and **orphaned oil wells** that can be transformed to energy storage infrastructure.
- **Repurposing infrastructure for gravity storage using underground potential energy (RIGS-UP)** has three major benefits:
  - No new infrastructure and more reliable source for grid resiliency
  - Quick power balancing response
  - Coverage for renewable energy fluctuations.



(a) (b)

Figure 1. (a) Documented orphaned oil wells in the United States (Source: *Environmental Defence Fund*); (b) RIGS-UP gravity energy storage system (Source: *NREL*)

2. Objective and Approach

- Evaluate the operation and control of RIGS energy storage system and **maximize drivetrain performance** (>75% round-trip efficiency).
- Evaluate a high-speed drivetrain system based on a **interior permanent-magnet synchronous motor (IPMSM)** rated for **30 Hp** and **1,800 rpm** in MATLAB/Simulink.
- Implement the regenerative operation using:
  - IPMSM fed through a pulse width modulation (PWM) converter.
  - Field-oriented control (FOC) of the grid-side and load-side converter.

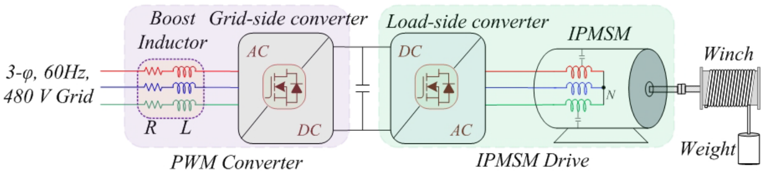


Figure 2. Power electronics system comprising an IPMSM fed through a PWM converter

3. Field-Oriented Control of PWM Converter

- FOC of PWM converter was implemented on grid-side and load-side converter to allow for:
  - **Four-quadrant operation** and voltage sag/swell compensation
  - **Unity power factor operation,** which ensures low amperage loss and higher efficiency.

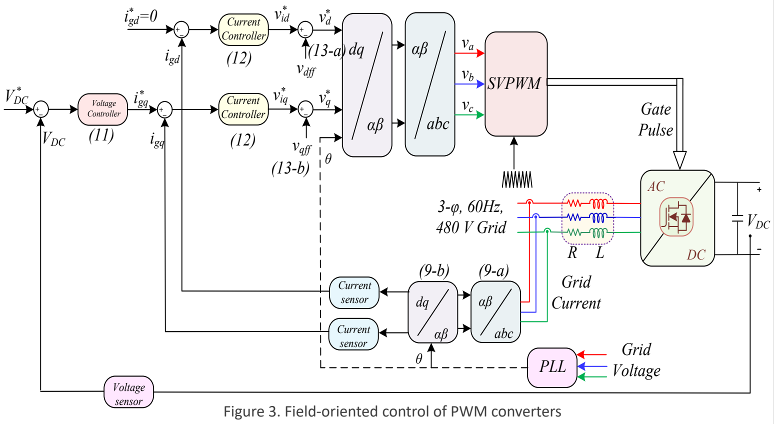


Figure 3. Field-oriented control of PWM converters

4. FOC of IPMSM

- Maximum torque per ampere (MTPA) control was implemented to **improve** the **efficiency** by **using reluctance torque.**

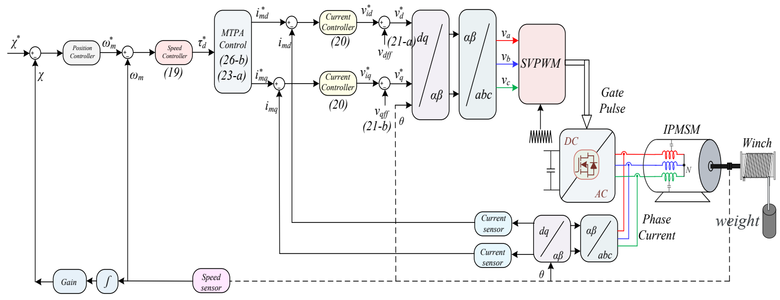


Figure 4. Field-oriented control of IPMSM with maximum torque per ampere control

5. Results

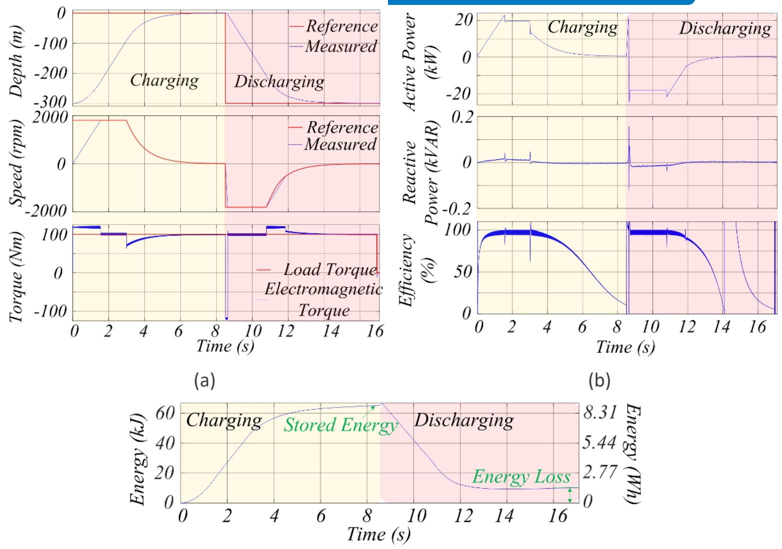


Figure 5. Performance of the gravity energy storage system: (a) depth, speed, and torque developed by the IPMSM; (b) active and reactive power delivered by the grid and the efficiency of the driveline during a round trip; (c) energy delivered by the grid during a round trip

- The electromechanical system ensures efficient power conversion by FOC of the electric machine and unity power factor operation of the grid-side converter.

6. Conclusion

- The electrical system achieves **85.9%** round-trip efficiency when storing 65 kJ of energy.
- The electrical system is **more efficient** during **charging** than **discharging.**
- The **minimum efficiency** occurs during **acceleration** and **deceleration.**
- The **efficiency** can be **maximized** by **increasing** the **ascent/descent** time: This can be achieved by using a **deeper well** or a **gearbox.**
- However, using a gearbox may incur additional **mechanical losses.**

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