Application Note: IPAN1004

Semiconductor Technology Selection for Solid-State Circuit Breakers (SSCBs)

1. Purpose and Scope

This application note discusses semiconductor device selection for solid-state circuit breakers (SSCBs) operating in AC or DC systems in the 600–1200 V class. The comparison focuses on B-TRAN©, SiC MOSFETs, SiC JFETs, and IGBTs, evaluated specifically against **SSCB operating requirements**, rather than general-purpose power conversion criteria.

2. SSCB Operating Characteristics

SSCBs differ fundamentally from power converters in both duty cycle and performance priorities:

- The semiconductor conducts current continuously during normal operation.
- Switching events occur primarily during fault isolation or protection actions.
- System performance is governed by:
    - Steady-state conduction loss
    - Fault interruption speed and controllability
    - Let-through energy (I^2t)
    - Electromagnetic interference (EMI)
    - Reliability under repetitive fault stress

As a result, device characteristics such as high-frequency switching capability or ultra-low switching loss, while important in converters provide limited benefit in SSCB applications.

3. Bidirectional Blocking and Conduction Requirements

Many SSCBs, particularly in DC distribution and AC protection systems, **require bidirectional blocking and conduction.**

- Devices that do not provide intrinsic bidirectionality must be implemented in back-to-back configurations.
- Back-to-back architectures increase:
    - Semiconductor count & cost
    - Conduction losses
    - Gate-driver count & cost
    - Control complexity

  - Thermal management effort
  - Failure points

This architectural consideration has a significant impact on system cost, reliability, and performance.

4. SSCB-Oriented Comparison

Evaluation Metric	B-TRAN©	SiC MOSFET	SiC JFET	IGBT
Steady-state conduction loss (SSCB duty)	Excellent	Good	Good	Fair
Intrinsic bidirectional blocking and conduction	Yes	No	No	No
Device count for bidirectional SSCB	1	4	4	≥4
Gate-drive and control complexity	Moderate	Moderate	Moderate	Low
Fault interruption controllability (I^2t)	Excellent	Good	Very good	Very good
EMI / dv/dt management	Excellent	Fair	Good	Good
Packaging and thermal simplicity	Good	Moderate	Moderate	Moderate
System-level semiconductor cost	Low	Moderate	Moderate	Low

Note: Ratings reflect system-level SSCB implementation, not individual device performance.

5. Device Technology Overview

B-TRAN©

B-TRAN© is an intrinsically bidirectional, conductivity-modulated semiconductor device. A single device can block and conduct current symmetrically in both directions, enabling simplified SSCB architecture with reduced device count, lower conduction losses and lower costs.

SiC MOSFET

SiC MOSFETs provide excellent switching performance and low per-device conduction loss. However, they are inherently unidirectional blocking devices and require back-to-back implementation for SSCB use.

SiC JFET

SiC JFETs offer strong conduction performance and high-temperature capability. Bidirectional SSCB operation requires paired devices, and gate-drive requirements, particularly for normally-on variants add design complexity.

IGBT
IGBTs are widely used and cost-effective but exhibit higher conduction losses and slower turn-off behavior, which can limit SSCB fault performance.

6. Fault Interruption and EMI Considerations

Fault interruption performance in SSCBs depends not only on turn-off speed, but on controlled current decay and manageable dv/dt.

- B-TRAN© enables controlled turn-off behavior that supports low I^2t and reduced EMI without aggressive gate shaping.
- SiC MOSFETs can achieve very fast current interruption, but high dv/dt often necessitates mitigation measures that complicate design and may reduce interruption effectiveness.
- SiC JFETs provide robust fault performance but retain the architectural penalties associated with paired devices.
- IGBTs exhibit slower current decay and higher interruption energy dissipation.

For SSCBs, predictability and controllability are more important than maximum switching speed.

7. System Cost and Reliability Implications

SSCB cost and reliability are strongly influenced by architecture rather than individual device price. Key contributors include:

- Number of power semiconductors
- Gate-drive circuits and isolation requirements
- PCB area and interconnect complexity
- Cooling hardware
- Assembly yield and long-term reliability

By enabling a single-device bidirectional implementation, B-TRAN© reduces system complexity and associated cost drivers while improving thermal uniformity and reliability.

8. Application Suitability Summary

- **Bidirectional AC and DC SSCBs**: B-TRAN©
- **Protection-focused static switches:** B-TRAN©
- **High-frequency power conversion:** SiC MOSFET
- **Rugged, specialized fault switching:** SiC JFET
- **Cost-sensitive, lower-performance protection:** Silicon IGBT

9. Conclusion

When semiconductor technologies are evaluated against SSCB-specific requirements, architectural simplicity, bidirectional capability, and controllable fault behavior dominate performance outcomes. Devices optimized for high-frequency power conversion introduce complexity that is not inherently beneficial in protection applications.

B-TRAN aligns closely with the operating conditions and priorities of SSCBs, offering intrinsic bidirectionality, low steady-state loss, simplified control, and favorable EMI behavior. These attributes translate into tangible system-level benefits in performance, cost, and reliability for solid-state circuit breaker designs.

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