

Replacement of Legacy Oil Based Circuit Breakers with Vacuum Based Circuit Breakers

Total Cost of Ownership Analysis based upon MEPPI 5 kV Circuit Breaker

MEPPI is introducing to the marketplace a 5 kV Vacuum Based Circuit Breaker that is unique in many ways. The Genesis of this product was to create a 5 kV Vacuum Based Circuit Breaker that would be a mission specific replacement for legacy, oil based circuit breakers.

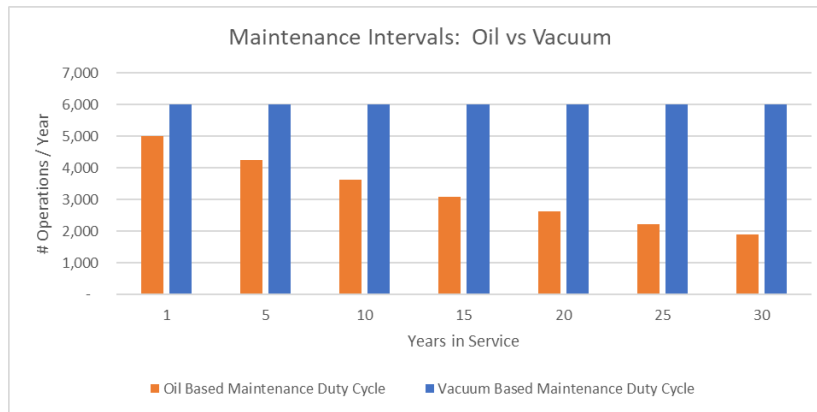


Figure 1. Maintenance Duty Cycle over time

Legacy, oil based circuit breakers have an inherently decomposing operation over time. Unwanted, high current superheats the oil, and by doing this creates a gas bubble that expands until it triggers the circuit breaker mechanism. There are five decompositional characteristics that need to be considered:

- As the oil super heats, it creates the byproduct of burnt carbon particles that will degrade the mineral oil over time. Every operation of the circuit breaker causes the oil to degrade.
- The oil tank must be filled part way with mineral oil, leaving an air pocket. This air pocket or impurities in the oil can introduced foreign objects and moisture that degrades the unit.
- The oil tank must be pressure sealed for the operational process to work effectively. The seals, plugs, tubes, connectors are at constant risk of breakdown under pressure.
- If gaseous buildup creates higher than acceptable pressure there is a vent that will allow gas to escape. This venting changes performance over time.
- Carbon, moisture, corrosion, foreign particles all can impact the contacts and conductive properties of the system, as the system can be opened and closed.

As a comparison, MEPPI vacuum based technology is made up of gaseous vacuum tubes that are sealed, without need of entry. There is no decompositional properties to these units. Furthermore, if defect is noted, the vacuum tube and the high charge module are plug N play. Plug N play means that there is no other remedy except to roll out the VPR module (including vacuum tubes and high charge module) and replace it. By doing this, it restores the unit.

As Figure 1 reflects, the oil based technology will require more frequent maintenance overhauls as it ages.¹ The vacuum based technology will not.² This will fundamentally drive most power utilities to seek higher efficiencies and lower cost with the MEPMI 5 kV Circuit Breaker replacement.

The second consideration is what does the maintenance of oil based circuit breakers versus vacuum based circuit breakers entail. Figure 2 reflects an estimate of the maintenance functions and costs associated with a given circuit breaker of each technology.

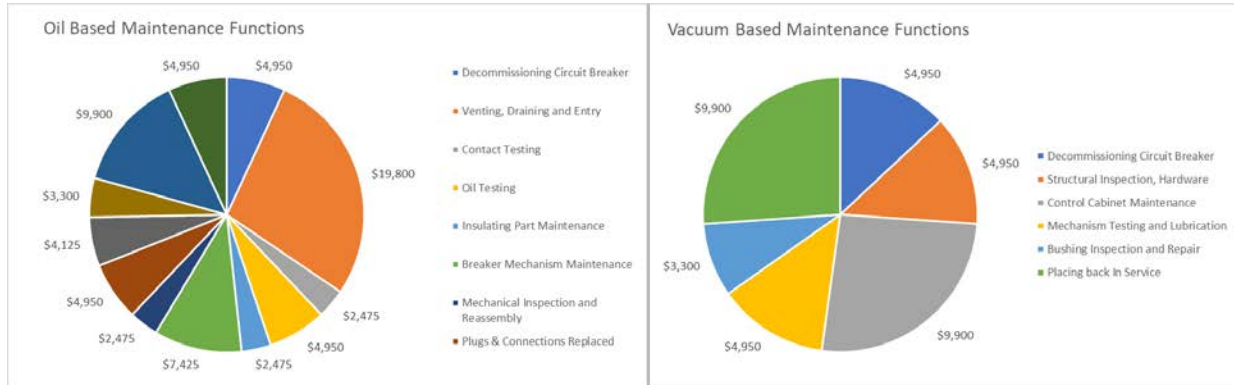


Figure 2. Comparison of the Maintenance Required and Estimated Expense

Sixty percent of oil based technology maintenance time and expense is associated with maintenance and restoration of the oil and oil tank apparatus. This would include venting, draining, testing, refilling and closing the oil tank. In the simplest comparison, the vacuum technology does not have this same time or expense. Because of this, the estimate is that a single oil based circuit breaker maintenance event costs roughly 435 man minutes and \$70,000. The vacuum based circuit breaker maintenance is 230 man minutes and \$38,000. On a per unit basis, the vacuum based circuit breaker is roughly 45% less expensive than the oil based circuit breaker.

While not addressed in this analysis, there are also many expense driven events, associated with oil based circuit breakers, that are significant. The unmeasured maintenance events might include any of the following issues:

- The cost of disposing of or reclaiming mineral oil that is drained from a unit, because it has been degraded below specification.
- The indirect costs of any gaseous or oil based leakage that will require cleanup or remedy.
- With many oil circuit breakers approaching 30 years of age, the problems of replacement parts have become a real issue. Often, these parts must be custom manufactured at very high expense.
- The problems associated with bulk, ergonomics and weight of working with heavy oil tank breaker units.

¹ GE Oil Based Circuit Breaker maintenance guide, and MAINTENANCE OF POWER CIRCUIT BREAKERS, HYDROELECTRIC RESEARCH AND TECHNICAL SERVICES GROUP, UNITED STATES DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, DENVER, COLORADO, December, 1999

² MEPMI User Guide, 5 kV Circuit Breaker

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Written by Steve Day, Steve Day Design and sponsored by MEPMI

A power utility with a substantial amount of oil based circuit breakers is faced with significant expense on an annual basis that is growing. In Figure 3, the TCO model has projected the maintenance cost relative to the number of circuit breakers in any given substation. It has also compared these costs to # of breaker operations per year. As expected, at 20 breakers per substation and at 8,000 operations per year; the oil based maintenance cost may be \$4.45 million. The Vacuum based maintenance cost would be roughly \$900,000. This difference is driven by differences in the maintenance duty cycle and the per unit maintenance expense. Again, in a real-world power substation, this portrays the profile of the two technology maintenance expenses.

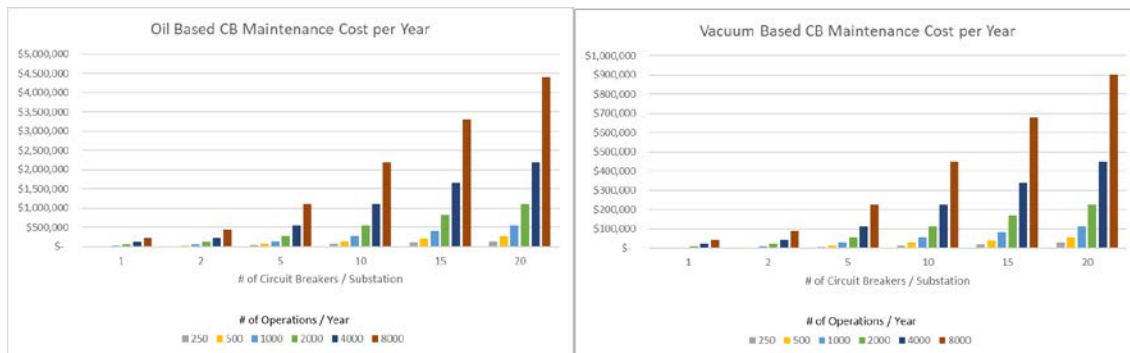


Figure 3. Comparison of Maintenance costs versus # of Breaker Operations and # of Breakers per Power Station

Finally, since the oil based circuit breakers are either fully depreciated or close to fully depreciated, it is important to understand how the purchase of new vacuum based circuit breakers can be viewed as total cost positive. Figure 4 is the summary of a detailed TCO (total cost of ownership) analysis relative to the number of circuit breakers deployed in any power substation. This is based upon 20-year-old, oil based circuit breakers with 2,000 annual operations/each. This is compared to being replaced by MEPPi 5 kV Circuit Breakers.

		Substation Size					
Total Cost of Ownership - MEPPi 5kV Replacement		1	2	5	10	15	20
	Model w/ 20 year old Oil Based Technology @ 2000 annual operations	Fully Depreciated					
	CB Maintenance Costs	\$ 54,999	\$ 109,999	\$ 274,997	\$ 549,993	\$ 824,990	\$ 1,099,987
		Or Invest in Vacuum Based Circuit Breakers					
	Replacement Cost - 5kV MEPPi CB	\$ 29,900	\$ 59,800	\$ 149,500	\$ 299,000	\$ 448,500	\$ 598,000
	Depreciated Expense (20 years) - SLM	\$ 1,495	\$ 2,990	\$ 7,475	\$ 14,950	\$ 22,425	\$ 29,900
	CB Maintenance Costs	\$ 11,275	\$ 22,550	\$ 56,375	\$ 112,750	\$ 169,125	\$ 225,500
	Total Costs	\$ 41,175	\$ 82,350	\$ 205,875	\$ 411,750	\$ 617,625	\$ 823,500
	Total Expenses (With Depreciation)	\$ 12,770	\$ 25,540	\$ 63,850	\$ 127,700	\$ 191,550	\$ 255,400
	TCO Balance - Total Costs	\$ 13,824	\$ 27,649	\$ 69,122	\$ 138,243	\$ 207,365	\$ 276,487
	TCO Balance - Annual Expense	\$ 42,229	\$ 84,459	\$ 211,147	\$ 422,293	\$ 633,440	\$ 844,587

Figure 4. TCO Analysis of the Purchase of New Vacuum Based Circuit Breakers

In this analysis, the “CB Maintenance Costs” represent the maintenance expense of the legacy oil based circuit breakers within a substation containing 1, 2, 5, 10, 15, or 20 circuit breakers, respectively. This is compared against the purchase of the MEPPi 5 kV Circuit Breaker, ranging from \$29,900 to \$598,000 of

capital investment. The next line is simply a straight-line depreciation of this capital across 20 years. Finally, when replaced, the vacuum based circuit breaker maintenance expense is also listed.

Using the example of 1 circuit breaker, \$54,999 of oil based circuit breaker maintenance expense would be eliminated. However, the vacuum based circuit breaker cost and first year maintenance would be \$41,175. On a cash basis, the replacement would result in a savings of \$13,824. On an accounting basis (including depreciation expense and excluding capital investment), the replacement would result in a savings of \$42,229. Therefore, it can be concluded that the replacement of oil based circuit breakers with vacuum based circuit breakers is TCO positive from year one and beyond.

As before, this does not take into consideration some very valuable aspects pertinent to replacement of 5 kV circuit breakers. The MEPPi 5 kV Circuit Breaker is two feet by two feet. It was designed this way so that it could fit on the same concrete pad as the oil based breaker units. It can be adjusted from five feet to eight feet, so that regardless of where the high charge multiphase input is, the MEPPi Circuit Breaker can be adjusted to fit into this space. There are a number of other attributes to discuss, but these two are specific considerations to the TCO analysis.