Circular ring main unit
White paper

The circular economy: A case study of design considerations for medium voltage switchgear

- What is the circular economy?
- Why proper design leads to lower total cost of ownership (TCO).
- How utilities and industrial users can profit.

Powering Business Worldwide

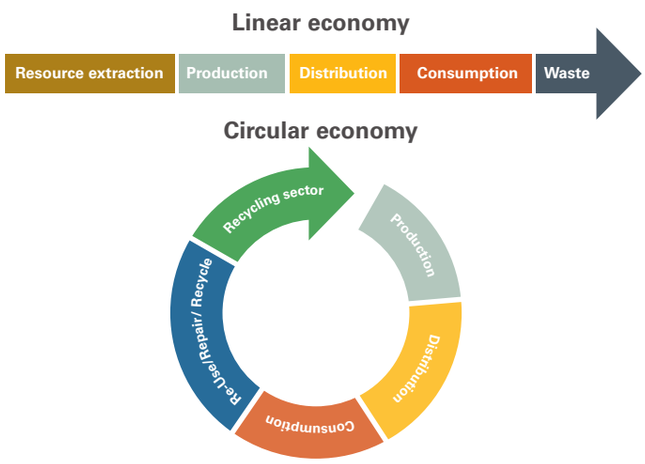
Introduction

The global exploitation of resources means that we reach the Earth Overshoot day earlier each year - the day that we (individuals and businesses) have reached our full allocation of natural resources we should consume for the entire year. Ideally, we could stay below this level entirely, but instead we reach it long before the 31 December target date, and we then go far beyond our required budget. To combat the ever-increasing demand for more and more natural resources, the circular economy demands that products, services and systems have no negative net effect on the environment over their lifetime. Waste must be minimized during manufacturing, use, and end-of-life disposal. For example, it is much better to avoid end-of-life disposal and instead repurpose into a second life use.

Reputable Medium Voltage switchgear manufacturers provide extensive information on the circularity of their offers. This is challenging, but it is incumbent that these companies provide a proper policy paper for customers to use to ensure that what they are acquiring fits their own goals for circularity. For Utilities, such switchgear is used extensively as Ring Main Units (RMU), and in this whitepaper we give insights about key circular choices an RMU manufacturer such as Eaton makes, and which should be part of the customer evaluation.

Linear economy versus circular economy

One of the most critical areas for circularity is the materials used in RMU systems. For example, copper is used extensively at all levels of electrical infrastructure. At current rates of usage and extraction, this critical material will be exhausted by around 2040 unless we change practices. We must move from the old "linear" economy to the "circular model" as shown below. This requires smart choices.



Circularity choices

The choices a RMU manufacturer must make, can be divided in four important circularity steps:

1. Designing for long lifetime and minimized service has the highest return for circularity
2. Using materials with the lowest greenhouse gas impact over the product's full life cycle
3. Using recycled materials as much a possible
4. Ensuring maximum recyclability of materials at end of life and in production

Fundamentally, these choices must consider all potential waste and impact on the environment – not just what happens while in use. Companies that buy RMU's need to understand and consider the environmental impact that goes into producing the units as well as how they will be disposed of or reused. It is no longer enough to only consider the impact while the RMU's are in active service.

Eaton approach

Eaton is a global manufacturer leader in producing power management products and as such has developed strong practices that are used in RMU design and manufacture. For example, Eaton is guided by MESH (Management of Environment, Safety, Security and Health), a globally deployed, unified system which consolidates existing programs into one integrated management system. All Eaton facilities worldwide work toward consistent goals – applying the same metrics, setting targets for improvement, and identifying and sharing best practices. MESH is also designed to conform to international standards such as ISO 14001 and OHSAS 18001/ISO 45001, and ISO 50001.

Eaton is committed to minimizing emissions to air, water and land resulting from operations. Eaton's Senior Leadership Council drives a sustainability strategy which establishes aggressive goals for reducing environmental impact. Using guidelines established by the Global Reporting Initiative, Eaton sets annual sustainability targets, and progress toward these is audited by third parties and reported. (Link: https://www.eaton.com/content/eaton/us/en-us/company/sustainability.html)

The Eaton RMU type Xiria product family follows these practices and the result is a sustainable answer to important modern-day and future energy challenges. With more than 100,000 panels shipped, the Xiria design uses a combination of solid material and dry air for insulation. The Xiria solid insulation technology allows the switchgear to be compact and still achieve high levels of performance. Xiria also does all switching in vacuum and therefore the only gas inside is air. By design, all materials used to produce and operate a Xiria system are safe for people and the environment. Because the system components are non-toxic, the product is easy to reuse and eventually dispose of with minimal environmental impact at end-of-life.

RMU designed for a long lifetime and operation

Eaton uses Life Cycle assessments (LCA) and Failure Mode and Effects Analysis (FMEA) for designing for a long lifetime. In terms of FMEA for Xiria switchgear, the tank for the primary system is sealed for life, including the mechanics which prevents the ingress of moisture and dust. The tank is robust without overpressure and the circuit breakers have a long lifetime (as opposed to alternative fuses). We can do retrofits on old switchgear and offer lifetime extension programs.

In addition, a deep analysis of Total Cost of Ownership (TCO) shows a big advantage for a self-powered protection relay in combination with a Circuit Breaker design. The benefits are a fraction of energy (Watt) losses, no replacement costs, and reduced inspection and maintenance. The Xiria design optimizes the electronic relay protection, keeping cost and floorspace to the absolute minimum.

Materials with the lowest greenhouse gas emissions per life cycle

Xiria is continuously improved through various programs, including Design for Environment (DfE) and Lifecycle Assessment (LCA), scientific processes that both identify a product's environmental aspects and potential impacts throughout its life cycle. There are five phases with CO_2 emissions:

1. **Components**
2. **Assembly**
3. **Distribution**
4. **Lifetime RMU**
5. **End-of-life**

1. Components

Each RMU manufacturer has important greenhouse gas emissions choices to make for insulation medium, switching medium and protection. Below is a description of each of these potential choices, and then which is used in the Xiria:

- **Insulation options:**
  1. SF_6 gas in stainless steel tank
  2. Air insulation
  3. Solid insulation
  4. A combination of solid insulation material with dry air in steel tank

The best option is the last one, and Xiria is designed with this combination of solid insulation plus air insulation in a sealed steel tank. Dry air is guaranteed due to the application of moist absorbing material inside the steel tank.

- **Switching options:**
  1. Open switching in tank filled with SF_6 gas
  2. In vacuum interrupter bottle

Xiria relies on Eaton vacuum interrupter bottles for both its Load-Break Switch panels and Circuit Breaker panels. Eaton vacuum interrupters are proven to be durable and reliable, and this avoids the pitfalls of switching in SF_6 which creates very dangerous byproducts.

- **Protection options:**
  1. Fuse in epoxy resin house
  2. Electronic relay in combination with a circuit breaker

Xiria uses circuit breakers instead of fuses which eliminates the need for epoxy resin housing which has a significant reduction in environmental impact at end of life.

The upshot of all the Xiria design choices is an RMU with a far lower CO_2 impact than switchgear designed using SF_6 and fuses. The table below shows the CO_2 impact by material type and total comparing a typical 3 panel RMU with SF_6 (Design 1) versus the Xiria RMU (Design 2).

Material CO_2 impact		**Design 1** Traditional design with SF_6 insulation, SF_6 switching and Fuse protection		**Design 2** Xiria with dry air/solid insulation material, vacuum switching and relay protection	
	CO_2 equivalent per kg	kg Weight	kg CO_2	kg Weight	kg CO_2
Stainless steel	6,15	83	510,45	5	30,75
Steel	1,77	133	235,41	307	543,39
Other metals	4,31	15	64,65	5	21,55
Copper	3,83	44	168,52	32	122,56
Epoxy resin	5,91	27	159,57	6	35,46
Plastics	3,00	5	15,00	37	111,00
SF_6 gas	23.900	2,5	59.750,00	0	-
		309,5	60.903,60	392,2	864,71

The Xiria design results in a 98.58% reduction in kg CO_2 for material used! It should be noted as well that the Xiria steel tank is dry-air filled. This design avoids using SF_6 gas. This provides an added and quite significant reduction in impact on global warming when compared to the majority of switchgear on the market which use this gas. For those gear, significant amounts of SF_6 will leak out during filling, usage, and the recovery process (if done) at end of life. Even for the best designs, it is estimated that up to 15% of the added SF_6 released into the atmosphere over equipment lifetime. Again, the Xiria completely avoids this issue by eliminating the use of SF_6 gas.

2 Assembly

The Xiria and most of its sub-assembly parts are built in a low carbon footprint factory in the Netherlands. This site makes use of on-site solar electricity production and wood burning boilers to reduce environmental impact. The resulting assembly $KgCO_2$ per RMU is a low 50kgCO2.

3 Distribution

Another factor in overall environmental impact is transport from production to end-user. The Eaton Netherlands production site where Xiria is produced is quite centrally located in Europe, and average impact for this factor is only 100 $kgCO_2$ per RMU.

4 Lifetime RMU

All RMU's lose some energy, but the Xiria has lower energy losses (25%) as compared with typical units because it uses circuit breakers instead of fuses. This means that energy losses in $kgCO_2$ per year average 200$kgCO_2$ per year for traditional SF_6 RMU with fuses versus 150$kgCO_2$ for Xiria with circuit breakers. Such units are designed to be used for a minimum of 30 years, and often are in the field much longer. During a 30-year lifetime, the reduction in environmental impact with a Xiria from just the energy savings alone will be 1,500$kgCO_2$.

The Xiria is also maintenance free by design. This reduces the amount of driving to and from the units, which has an add on savings on CO_2.

5 End-of-life

The Design for Environment (DfE) choice with the biggest environmental impact is to avoid the use of SF_6 gas for insulation and switching – which is what the Xiria does. This was a key consideration in the design of the Xiria and the Eaton range of SF_6-free switchgear.

A bit of background concerning SF_6 use in electronic switchgear. For many years, Switchgear used oil or just air. Moving to SF_6 gas (a very good insulator) allowed such equipment to become much more compact, and SF_6 usage became standard for many switchgear. However, it is now well understood that SF_6 gas is the worst of all the greenhouse gases, with a global potential 23,000 times that of CO_2. This was called out clearly in the Kyoto protocol, and advanced systems are designed to minimize the leakage of SF_6 during operations. However, as mentioned above, this is not sure or controlled, and in any case, significant amounts of SF_6 are also released during filling and at end of life even under best conditions.

Eaton's policy is to avoid harmful substances, and this was a key reason for the decision to design the Xiria family without SF_6 gas.

EU F-gas Regulation 517/2014:

In fact, the use of SF_6 gas was mostly banned in 2014 by the European Union (EU) F-gas Regulation, which is part of the overall drive to mitigate climate change. Since then, shoes, windows or tires must all be SF6-free, but a few products were exempted due to concerns about the availability of suitable alternatives.

This legislation foresees a full ban on 24 kV medium voltage switchgear relying on F-gases in 2026, with a phase-out by 2030 of switchgear with 36 kV.

Already, costs for the disposal of older equipment containing SF_6 have increased significantly as a result of additional requirements for handling this gas, driving up the total cost of ownership. However, green switchgear options are now more widely available, and among these, our proven Xiria range demonstrates that SF_6 can be eliminated without any loss of performance and at a lower total cost of ownership.

Using recycled materials

Eaton's policy is to purchase materials with the highest available recycled percentages. In terms of Xiria, recycled steel and copper is purchased whenever possible. Metal scraps from the assembly locations in the Netherlands are sent to TSR Recycling in the Netherlands. This scrap can then be recycled into new metals.

Recyclability of materials

The Eaton Xiria is also designed for full recycling at end of life. This involves the materials used to manufacture the gear as mentioned above, but it is also important that it is easy to separate materials at end-of-life so that they can go to the right recycling processes. In Xiria systems, the tank is not welded so that the different materials can be taken apart easily. This is in contrast with more traditional RMUs on the market where disassembly is difficult, and materials will be toxic due to open switching in SF_6. For SF_6 handling at end-of-life see also IEC 62271-4. To avoid SF_6 handling at end of life, simply use green-switchgear such as the Xiria.

Conclusion

We live in a time where there is greatly increased understanding of our impact on our environment and how choices we make now will affect our lives in the future. Circularity, like most sustainable practices requires effort and sometimes a small increase in initial purchase costs, but the gains are significant and the return on investment make this worthwhile. Customers of RMUS (Ring Main Units) increasingly require companies to demonstrate full life circularity from manufacture to end of life. To achieve best results requires careful and smart choices by manufacturers of medium volt equipment that include materials, lifetime, serviceability, logistics, and recycling.

Eaton has considered each of these choices carefully and the result is clear. The Xiria family of RMU's achieves better than 98% reduction in impact as measured by CO_2 on the environment. Significantly, the design of the Xiria resulted in the use of solid and dry air insulation and circuit breakers. In particular, eliminating the use of SF_6 gas lowers both the environmental impact and cost of ownership significantly. It is fully expected that the EU will soon eliminate the exception for switchgear and ban the use of SF_6. Even for grandfathered equipment, we can expect much more stringent controls on monitoring and accounting of SF_6 over the entire life of equipment driving up costs for their owners.

Considering environmental impact and circularity is increasingly understood to be needed to address impact on the environment and to reduce overall costs. At Eaton, we have designed this into the Xiria RMU and the units provide low environmental impact and low cost of ownership. It is now incumbent on Utilities and other customers of RMU's to really consider the full life cycle costs and make the right decision on equipment they procure. This is not only the right thing to do for our planet and future, it is also the smart way to improve overall profitability.

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