INNOVATION STRATEGY CLOSE-OUT REPORT

PROJECT TITLE	Introduction of Amorphous Core Transformers
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BRIEF OVERVIEW OF PROJECT & EXPECTED BENEFITS

Introduction of amorphous core transformers has the potential to reduce ESB Networks (ESBN) distribution losses. Hysteresis and eddy current losses occur in the magnetic core of a transformer. These losses are incurred whenever the transformer is energised – which is 24/7 for distribution transformers.

These losses can be reduced by manufacturing the transformer core from amorphous steel. Amorphous steel is manufactured by rapid cooling from molten to solid state. This process ensures no crystalline structure is formed. The amorphous (non-crystalline) structure reduces hysteresis losses.

The thickness of amorphous steel is typically 0.03 mm. This is approximately 10% of the thickness of conventional steel used for transformer cores. The reduced thickness decreases eddy current losses.

ESB Networks has trialled various amorphous core pole-mounted transformers over the last 20 years. The technology is now considered sufficiently mature to include the option of purchasing amorphous core transformers in ESBN's general enquiry for pole-mounted transformers.

Electrical losses have an economic value in terms of both the value of the energy saved and the reduction in CO2 emitted by not having to generate such energy. However, the purchase price of the amorphous core transformer is higher than a conventional transformer. Amorphous core transformers should be procured where this cost differential is less than the value of the saving made.

Therefore, in terms of amorphous or traditional transformer technology the issue is which technology would give the most economic impact to the customer. Having two competing technologies in the tender also means that traditional and new manufacturers are competing with each other to produce better solutions. Whilst it is very difficult to assess the benefits which arise from such competition in areas where traditional transformer technology continues to win the tender, it can be assumed that this is at a lower price than would have been the case had there not been increased competition from amorphous transformers.

The extra option of amorphous was included in ESBN's most recent enquiry and tender submissions were evaluated in 2018.

RESULTS

ESBN evaluates transformer tenders on the basis of Total Cost of Ownership (TCO), which is the sum of:

- Purchase price of transformer
- Capitalised cost of core and winding losses for the lifetime of the transformer

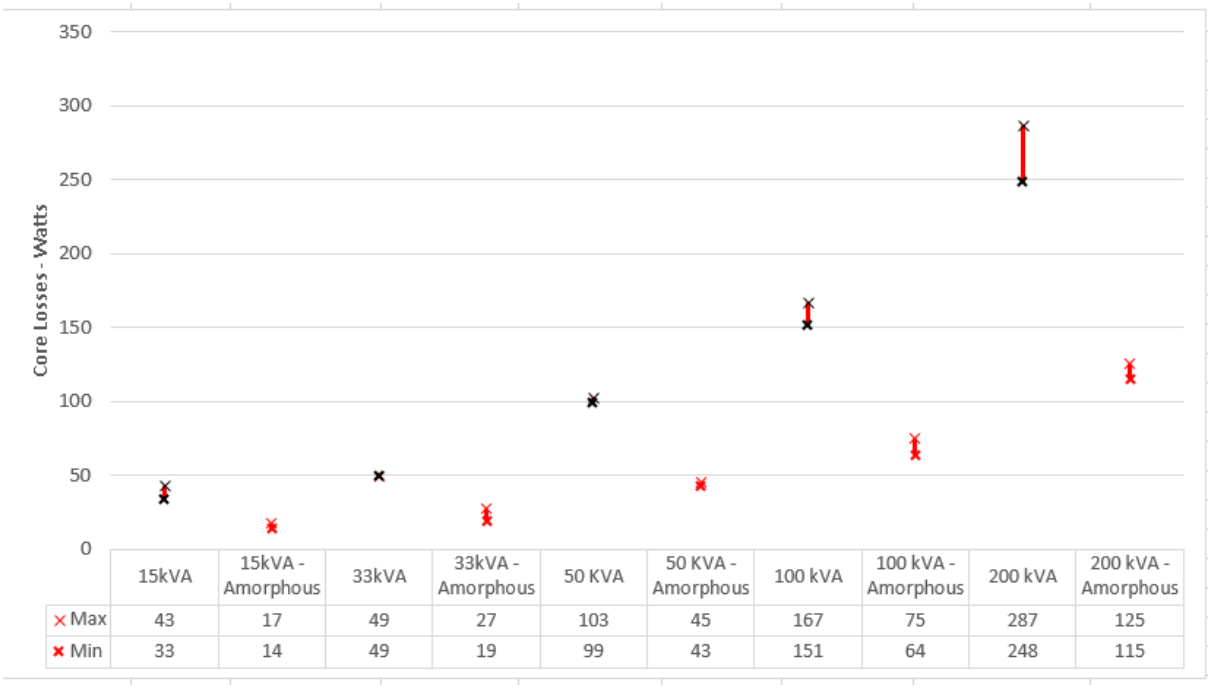
For the most recent tender, Suppliers were told ESBN would capitalise transformer losses on the following basis:

Transformer Type	Core Losses (€/kW)	Winding Losses (€/kW)
1-Phase	9,500	400
3-Phase	9,500	920

TABLE 1. CAPITALISED TRANSFORMER LOSSES

ESBN 15 kVA and 33 kVA transformers are 1-phase, all others are 3-phase. Suppliers used this information to optimise the balance between manufacturing costs and minimising transformer losses.

Fig. 1 shows the core losses guaranteed by suppliers for transformers with conventional and amorphous steel cores respectively. The core losses for amorphous core transformers were less than 50% of the value for the equivalent transformer with conventional core in all cases. There was less than 10% variation in guaranteed winding losses between the two types of transformer.



	15kVA	15kVA - Amorphous	33kVA	33kVA - Amorphous	50 KVA	50 KVA - Amorphous	100 kVA	100 kVA - Amorphous	200 kVA	200 kVA - Amorphous
× Max	43	17	49	27	103	45	167	75	287	125
× Min	33	14	49	19	99	43	151	64	248	115

FIGURE *1*. GUARANTEED CORE LOSSES FOR CONVENTIONAL AND AMORPHOUS CORE TRANSFORMERS

1-phase amorphous transformers are more expensive than transformers with a conventional core. However, in the particular case of a 50kVA 3-phase transformer, the TCO of the amorphous core version is less than the conventional equivalent i.e. the savings in capitalised losses more than offset the additional cost in manufacturing the transformer. In general, the capitalised losses are a more significant percentage of the TCO for 3-phase transformers.

Some of these savings are due to ESBN specifying 20 kV single-ratio amorphous core transformers. The conventional transformers are dual-ratio, capable of operating at 10 or 20 kV. This difference accounts for 2 to 3% of the price difference.

LEARNINGS

Transformers with amorphous steel cores have some different characteristics to transformers with conventional cores:

Care in manufacture

The amorphous steel laminates are very delicate. Thickness is typically 0.03 mm. Experience is required to manufacture high-quality amorphous cores. Only one of the two companies submitting bids for amorphous cores was considered to have the required experience.

More bracing required

More bracing is required to support the core manufactured from delicate amorphous steel. The amorphous cores have sharper turns and hence a higher concentration of mechanical stress at the corners. This means that for short circuit requirements the 'corners' need to be more securely braced so as to prevent core movement.

Lower flux density

Flux density for amorphous core transformers is often limited to between 1.3 – 1.4 Tesla at rated voltage in order to maintain transformer noise within the limits specified. In contrast the specified flux density is higher for conventional transformers – in the range 1.4 to 1.7 Tesla. This means that more amorphous steel is required to achieve the lower flux density, making it less economic as a solution.

Larger transformer

The requirement for a lower flux density and more bracing, can result in a larger core and transformer housing. However, the tender indicates that it is possible to manufacture 1-phase amorphous core transformers that are lighter than the conventional equivalent. It was also seen that 3-phase amorphous core transformers were heavier than the conventional equivalent in all cases, although within the required weight limits.

		Amorphous		Conventional	
Transformer kVA	Specified Maximum Weight (kg)	Supplier 1	Supplier 2	Supplier 1	Supplier 2
15	200	<200	>200	<200	<200
33	300	<300	>300	<300	<300
50	500	<500	>500	<500	<500
100	750	<750	<750	<750	<750
200	1100	<1100	<100	<1100	<1100

TABLE 2. TRANSFORMER WEIGHTS

Tank volume increases by up to 30% to accommodate a 3-phase amorphous core. Figures from one manufacturer indicate that tank volume is more than 20% less for a 1-phase amorphous core.

Higher noise level

Amorphous core transformers have higher noise levels. However, values quoted by suppliers are within ESBN's specified limit. It is particularly evident from at least one supplier that they can manufacture conventional 3-phase transformers with an average sound pressure level 6 dB less than a transformer

with an amorphous core. Units for sound pressure level are a dB logarithmic scale where every 3 dB rise represents a doubling in sound pressure.

		Transformer kVA				
		15	**33**	**50**	**100**	**200**
Transformer Core Type	ESBN Specified limit	44	44	46	46	46
Amorphous	Supplier 1	< 44	< 44	44	46	46
	Supplier 2	< 44	< 44	< 44	< 46	< 46
Conventional	Supplier 1	42	40	40	40	40
	Supplier 2	< 44	< 44	< 44	< 44	< 44

TABLE 3. AVERAGE SOUND PRESSURE LEVEL, LP.3 - DB

BENEFITS REALISED/VALIDATED

450 single-ratio 3-phase 50 kVA transformer with amorphous cores shall be purchased. The reduced core losses will reduce distribution losses by 25 kW, which represents a capitalised saving of €240,000 for transformers expected to be purchased in this tender.

NEXT STEPS – BAU, TRANSFER OF OWNERSHIP

ESBN will gain more experience with amorphous core transformers during this contract. Amorphous core transformers may be more cost competitive by the time the next enquiry issues. Analysis of the pole-mounted transformer enquiry indicates there may be scope to purchase ground-mounted MV/LV transformers with amorphous cores. This will require a more detailed analysis of the load factors, as these may increase significantly on newer ground mounted transformers feeding concentrated loads due to the increased electrification of heat and transport. As amorphous core transformers have lower core losses than conventional designs. The winding/copper losses are related to the load factor of the transformer e.g. a transformer that is under used will have very low copper losses and one with greater usage will have higher losses. The electrification of heat and transport will effect these load factors and thus will have an impact on the TCO analysis.

FINAL TIMELINES (REASONS FOR ANY DELAYS IF THEY OCCURRED)

No delays.

FINAL COSTS

No additional CAPEX or OPEX costs. Purchase of 50kVA amorphous core transformers only was recommended because the TCO was less than the cost of similar transformers with conventional cores.