Design and delivery of Ireland's largest transformer

500 MVA - 400 kV - 540 tonnes

ABSTRACT

Due to constraints in the Irish transmission system, the Irish Transmission System Operator called for increased capacity in the network to cater for increased renewable generation by adding a 500 MVA, 400 kV transformer and a new 400 kV GIS substation on the Atlantic west coast. Due to the network configuration, the insulation level of Ireland's 400 kV system is rated at 550 kV, resulting in more stringent requirements for design and testing to ensure insulation coordination.

A detailed functional and technical specification was produced, which included stringent requirements for corrosion protection, over-fluxing, short circuit withstand, impedance envelope, conditional monitoring, testing and delivery.

Delivery and installation of this large transformer to the remote location of the site, prone to heavy Atlantic swells and gale force winds, took place in winter, which increased the risk of moisture contamination of the oil and RIP-type bushings. Through careful planning and coordination, the entire operation worked out successfully.

KEYWORDS

specification, design, manufacture, delivery, installation

1. Introduction

Under the National Renewable Energy Action Plan (NREAP), submitted to the European Commission in July 2010, the Irish government has committed to 40 % of electricity generated from renewable sources by 2020. EirGrid, the Transmission System Operator for Ireland, has established the Grid 25 programme [1] to marry together this government target and the anticipated needs of existing and future grid users. Grid 25 is a high-level strategy outlining how EirGrid intends to undertake the development of the electricity transmission grid in the short-, medium- and longer-terms to support a long-term sustainable and reliable electricity supply.

It seeks to implement the provisions of the 2007 Government White Paper on Energy – *Delivering a Sustainable Energy Future* for Ireland in terms of development of electricity transmission infrastructure.

To date, wind energy (21 % in 2015) [2] is the main source of renewable electricity generation in Ireland. The current total wind capacity is over 2,000 MW generated from over 190 wind farms, mainly consisting of wind farm clusters in the north-west and south-west of the island. The redevelopment of Moneypoint 400 kV GIS substation is the key gateway in delivering this wind generation from the south-west of the country to the main load centres in the east of Ireland.

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The focus of this article is to outline the development of this project and its timelines along with the key technical issues unique to the Irish 400 kV system that had to be considered and managed in the selection of the transformer.

The normal IEC [3] BIL (Basic Insulation Level – an indicator of dielectric strength), i.e. Lightning Impulse Withstand Voltage requirement for a 400 kV system is 1425 kV. However, calculation and experience have led to a policy of requiring a BIL of 1550 kV – a value normally associated with a 550 kV system, for equipment used on the Irish 400 kV system. The most straightforward solution would have been to buy the normal 550 kV systems available on the market. This would have resulted in a higher cost and a much bigger footprint, and also a substantially bigger building, so the specification was written to try to obtain 400 kV GIS with some additional performance requirements rather than the default alternative of 550 kV.

2. Specification

If you don't ask for it, you won't get it. Thus, if your specification is not detailed, don't expect the manufacturer to know what you want [3, 4, 5, 6, 7]. They have to manufacture for various customers and will not have a standard 'recipe' to work from.

Therefore, all the required standards according to which this transformer had to be manufactured were listed.

2.1 Specific requirements

To ensure complete compliance with customer specifications, specific requirements were detailed. This included impedance values ranging from >13 % on the lowest tap to <14 % on the highest tap, short circuit levels of 50 kA and a dynamic peak level of 125 kA for the 400 kV level, acceptable partial discharge – 40 pC, full details on painting, corrosion specification, paint tests, transport and installation.

2.1.1 Partial discharge

IEC 60076-3 [3] requirements for partial discharge are specified at 200 pC, which does not allow for any deterioration of equipment during use before this level is exceeded. Specifying a maximum allowed level of 40 pC, which is achievable, allows years of equipment use before reaching this level.

2.1.2 Painting and corrosion protection

The environment in Ireland is extreme corrosive and the location of Moneypoint Power Station is historically the worst for outdoor equipment. In order to overcome this, the specification requires a C5M, ISO 12944 [7] – (marine environment) type of corrosion protection level. This specification details the tank preparation, painting requirements and testing required on the painting system as applied. Due to excessive moisture ingress, the transformer cover had to be welded in place to prevent this from happening.

2.1.3 Transport and delivery

Due to the size of the transformer – 11 m (L) x 4 m (W) x 4.7 m (H), the location of the substation and the condition of rural roads in Ireland, this transformer could not be delivered by road. The specification included details of the required delivery

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Because of very stringent specifications, some manufacturers had to withdraw from the tender process due to their transformer being too big to transport on the roads in their own countries

Figure 1. Transformer in port

by sea, Shannon River and utilisation of the power station's internal roads. With winter storms in Ireland being very severe, the time window for delivery is very narrow, i.e. two to three weeks. Once the storms start, the jetty is at risk of being damaged by rocks and severe storms will also put the transformer at risk of falling into the sea. This all had to be included in the delivery planning.

2.1.4 Impedance, insulation and short circuit levels

With the required insulation level not equivalent to the standard of 400 kV, specific details for all insulation levels needed to be specified, i.e. 1550 kV for lightning impulse. As this transformer also needed to meet specific voltage – 17 taps ranging from 350 kV to 420 kV, and impedance requirements (X/R ratios ranging from 47 to 57.8), these values had to be specified, resulting in a two-winding transformer with a massive size and weight totalling 550 tonnes. Because of this, some manufacturers had to withdraw from the tender process due to their transformer being too big to transport on the roads in their own countries.

2.2 Design including theoretical short circuit

The supplier chosen for this transformer is from Italy. A design review was performed by specialists from the Irish utility, who also visited the factory for a Quality Audit and audit of the Quality Management System. The documents as well as the factory was audited, including the sub-suppliers of the tank and core. All design documents, including the theoretical short circuit levels as specified in IEC 60076 [3], were checked. The theoretical

calculations were accepted, due to the high cost of having a transformer short circuit tested at one of the internationally recognised test laboratories like CESI or Kema.

2.3 Follow-up inspections and testing

Bi-monthly inspections on the progress of the manufacture were performed.

The transformer passed the Factory Acceptance Test in September 2016. Special attention was given to the lightning impulse and chopped wave lightning impulse tests, as these were deemed to be the most severe for this specific transformer.

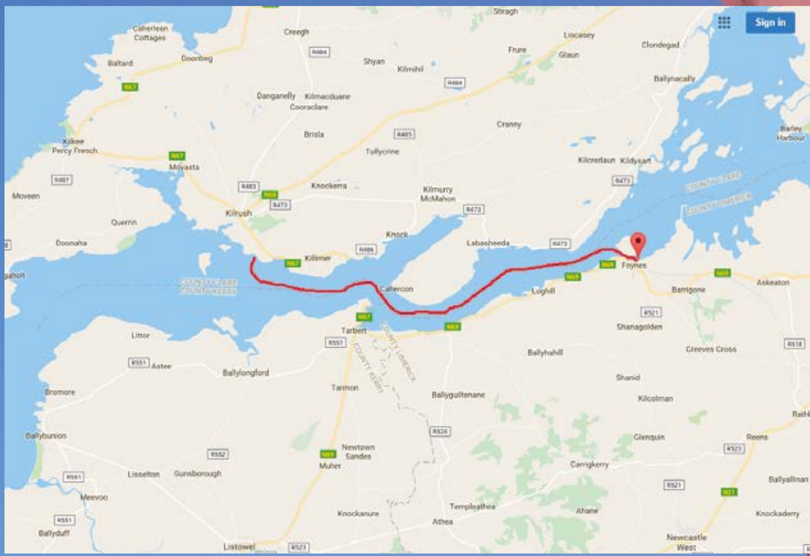

Figure 2. Route of the transformer from Foynes to Moneypoint

The partial discharge was also well below the required 40 pC.

After the cover was welded on, and the welded section painted and tested, the transformer was loaded onto the transport system. Due to its size, and the fact that it was also a first of its size for Italian roads, special permits had to be obtained to transport the transformer from Legnano to the Italian coast – a trip which took seven nights to complete.

2.4 Transport

The transformer was transported by girded trailer (at least 100 m in length) from Legnano in Italy by road 300 kilometres to the port at Chioggia in Italy, where it was loaded onto a ship. This road trip took seven days as the cargo was only allowed to travel at night. From here, the transformer was transported to Foynes in Ireland, and this trip by sea took about 15 days. In Foynes, which is located in the Shannon Estuary, the transformer was offloaded onto a self-propelled trailer on top of a barge. The trip from Foynes back up the Shannon to Moneypoint took one night, and on the next morning as the tide went out, the barge was landed on the Moneypoint jetty. The heavy lift contractor built the ramps

The delivery of the 550 tonne, 500 MVA transformer during winter storm season posed many risks which had to be mitigated

Figure 3. Transformer being off-loaded from the ship onto the barge

and the transformer was driven off the barge to the power station. The trip to the substation about two kilometres away took about four hours.

2.5 Delivery and placement on plinth

The two kilometres, approximately, from the jetty to the station were done in about six hours from the roll-on roll-off pontoon to the plinth, utilising a self-propelled trailer.

Once on the plinth, the transformer was placed on wooden blocks and jacked down over a period of one and a half days. Just before final placement, the anti-vibration material was installed beneath the cross beams. Where the utility previously used hardwood, the decision was made to utilise manufactured materials – similar to those used in buildings in earthquake prone areas.

3. Assembly and final commissioning

The final assembly started the day after placement. Assembly was done outside, with no cover against the elements, and due to the rainy season, assembly had to be done as quickly as possible to get all the accessories installed and not letting them lie outside in the rain, drawing moisture. With rain being almost a daily feature in Ireland, this did not deter the utility staff in completing their task as quickly as possible.

The oil import caused one of the biggest issues, in that the type of oil requested is classified by Irish customs as a fuel oil, and as such permits and tax clearances had to be arranged. After many different issues and many tax queries, it was approved and the four tankers with the oil were sent to the power station. Here, the oil treatment and filling started, which lasted six days, and the bushings were also installed.

For this transformer to be up to date with asset management, an asset management system for transformers manufactured by one of the major European brands was selected. This system allows the transformer condition to be monitored remotely, and also allows adding up to four other transformers on this system, and all information being displayed on a web address.

Conclusion

With a proper specification, detailed monitoring, and a lot of planning and effort, a good transformer can be specified, designed, manufactured and delivered to site. This requires a lot of coordination and effort from various people in different countries, but in the end ensures a very successful venture. This 550 tonne, 500 MVA transformer took seven days from the factory to the port and another two weeks to reach the site. Here it was offloaded and installed using tried and tested techniques. Although this transformer is not yet energised – energisation will take place in the next two months – it will ease the loading on the 400 kV system and strengthen the 400 kV transmission system which should reduce the risk on the 400 kV transmission system.

With a proper specification, detailed monitoring, and a lot of planning and effort, a good transformer was specified, designed, manufactured and delivered to a rural site under severe conditions

References

[1] Eirgrid, *Grid 25 - Grid Implementation programme*, 2011 – 2016

[2] Irish Wind Energy Association, Wind Energy Statistics, obtained from http://www.iwea.com/windstatistics

[3] IEC 60076-3, Insulation levels, dielectric tests and external clearances in air

[4] ABB, Evaluation of Short-Circuit Performance of Power Transformers

[5] ABB Transformer Handbook

[6] ESB Specification 17003

[7] ISO 12944, International standard on corrosion protection of steel structures by protective paint systems

Author

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