

Transformers as district heating boilers

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To minimise the energy waste in this inner-city transformer substation National Grid employed a novel heat recovery solution.

In a world where the requirements of urban planning regulations and an ever increasing demand for electricity have to be met, transmission grid operators face new challenges when they have to facilitate network expansion in city centre environments. As part of a complex 400 kV cable expansion programme across London, National Grid, the owner and operator of the electricity transmission system in England and Wales, was faced with the task of convincing planning authorities that it could build a 400 kV electricity substation in a densely populated urban area with minimum impact on the surroundings. As well as minimising the required space and satisfying stringent planning requirements, it was considered necessary to provide an innovative substation solution with a focus on the needs of the local community.

The area in question is Highbury, a densely populated suburb close to central London. In February 2014 Siemens was contracted by National Grid for the turn-key supply of a total of three grid transformers, each rated at 240 MVA and 400/132 kV, complete with a cooling system with heat recovery. The concept for the basic transformer configuration focused on the following key requirements:

- minimum transformer footprint
- maximum flexibility of site configuration
- harnessing electrical losses
- reduced fire risk
- minimum radiated sound power level.



The insulating fluid in power transformers doubles as a coolant. It is pumped through the transformer and also drawn through it by thermal siphoning. The warm coolant is then sent to a suitable cooler. In order to minimise the transformer footprint the decision was made, in a break from what could be considered to be the established standard solution utilising free-standing radiator banks which emit heat into the surrounding air, to utilise oil/water heat exchangers for the job of cooling the transformers.

The decision brought with it its own challenges in that the transformers would be reliant on the operation of the coolers to remain in service. A traditional cooling system utilising radiators will continue to dissipate heat in the event of the loss of its auxiliary power supply for cooling pumps and fans. In order to guarantee resiliency of the cooling circuit, the transformers were configured so that the power supply for each transformer's cooling system was fed from the transformer itself, ensuring that it was independent of a separate power supply.

To further maximise the flexibility of the configuration and reduce the substation footprint the oil/water coolers were used in conjunction with water/air coolers which could be mounted on the roof of the building containing the transformers.

District heat utilisation

In order to maximise the overall efficiency of the system and minimise waste heat loss the transformers were configured so that their electrical losses could be captured in the form of hot water which is then fed to a local district heating scheme serving a school and residential buildings near the substation.

The facility to recover waste heat generated its own set of challenges. In order to maximise the capacity for heat recovery, the level of waste heat dissipated by the transformers released into the surroundings had to be kept to an absolute minimum. It was also necessary to ensure a constant cooling water output temperature irrespective of the amount of power flowing through the transformers. This was achieved by means of a combination of thermal insulation at the transformers and development of a complex programmable logic controller to regulate the transformer operating temperature.

The system was configured in such a way that with all three transformers in operation the levels of waste heat shown in Table 1 could be recovered to supply the district heating scheme:

Ester based insulant

The requirement for a reduced fire risk, given the immediate proximity of the substation site to high density residential housing, led to the decision to utilise an alternative insulating/cooling fluid for the transformers. As an alternative to mineral insulating oil, which can be considered to be the industry norm for this type of transformer, it was decided to utilise a synthetic ester. Synthetic esters are biodegradable and in comparison to standard mineral oil have a high fire point. This is the temperature at which the vapour produced will continue to burn after ignition by an open flame. Making use of synthetic ester at a voltage level of 400kV constituted a world first and afforded Siemens the opportunity to perform significant R&D work on the subject before putting the transformers into production.

Heat rejection

To cope with the eventuality that the transformers could be in operation when the demand for waste heat was insufficiently great to adequately dissipate their combined losses, the cooling system was configured to include a facility for the rejection of waste heat, namely the cooling fans mounted on the substation roof. These coolers enable the hot water from the secondary side of the oil/water heat exchangers to be dissipated. Their primary components are tube heat exchangers to transfer the heat from the water to the surrounding air, and the cooling fans. The proximity of the installation to residential dwellings and the school meant that the specified noise pressure level for the coolers had to be 30dB(A) at a distance of 10m. This is comparable to a human whisper. In order to meet this requirement, ultra-low noise cooling fans were developed specifically for this application and the coolers were fitted with additional silencers.

The transformers with their associated cooling and heat recovery systems were supplied by the Siemens transformer factory in the town of Weiz in Austria. They successfully underwent factory testing during the period from March to July of 2015 and were scheduled to arrive on site in Highbury

at the end of 2015. Site installation works are scheduled to be completed in 2016 with the entire scheme expected to enter service in 2017.

