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Network & equipment development of FACTS to enable greater renewables penetration in Ireland – developments and Roadmaps for alternative technologies

Robert le Roux,
Ralph Morgenstern, Eben Mans & Thomas Schlegl

Ireland / Germany

Robert.leroux@esb.ie & ralph.morgenstern@siemens-energy.com & eben.mans@esb.ie & thomas.schlegl@siemens-energy.com

SUMMARY

Due to the increase of renewables into the Irish grid and in order to meet the low carbon emission targets of 75% for 2030, the Irish Utility decided to install various FACTS devices, including STATCOM with active filtering.

With the requirement to provide power of a high quality and low harmonics, meeting established Grid Codes, new technology has to be added to the network that will allow carbon emission reduction without disruption to the existing network.

This paper explains the technology chosen, the effects on design and layout of the substation and the advantages obtained by adding FACTS devices to the network. Also, the process of adding it to the network with the minimum amount of disruption to the existing network.

The Irish Utility installed two 110 kV STATCOM's (Static Synchronous Compensator) using VSC technology on the major 220 kV lines that feeds the wind-energy in the Southwest of Ireland to the major energy distribution hub at Moneypoint PowerStation on the Westcoast of Ireland.

A system study was performed by the National TSO to determine the required level of compensation and also the level of harmonics present in the Irish transmission system.

A novel / new technology utilised in this is the inclusion of a **four** frequency active filter that allowed for the reduction of harmonics without the inclusion of the large space requirements of having four passive filters. In this case a single frequency passive filter is used to reduce the biggest harmonics of the 3rd order.

For the supplier this is the first installation of a four frequency active filter system combined with a ±100 Mvar STATCOM.

A further ±30 Mvar STATCOM, not utilising active filtering was installed on another transmission line in the centre of the country.

KEYWORDS

Network & equipment development, FACTS, greater renewables penetration, Ireland, STATCOM, transition to low carbon generation, harmonics, active and passive filter

Abbreviations

MMC:	Modular Multilevel Converter
FACTS:	Flexible AC Transmission Systems
SVC:	Static var Compensator
SVC PLUS:	Supplier's STATCOM solution
PCC:	Point of common coupling
STATCOM	Static Synchronous Compensator
IGBT	Insulated Gate Bipolar Transistor
TSO	Transmission System Operator
VSC	Voltage Source Converter

1 Introduction

Due to the significant increase of renewables in the form of mostly wind generation, connected and planned to be connected into the Southwest of the Irish grid in the order of about 1700 MW. Most of this planned generation are connected into the 220 kV network via a significant amount of 110 kV and lower voltage cables. In addition, there are also 220 kV cables installed between Moneypoint and Knockanure stations to facilitate the export of excess generation from the area. All these cables contribute to high voltage during low wind scenarios. In order to meet the low carbon emission targets of 75% for 2030, the Irish Utility decided to install STATCOM's with active filtering on this line.

2. Considerations in installing FACTS in Substations

With the requirement to provide power of a high quality and a low level of harmonics, meeting established Grid Codes and power quality standards, new technology has to be added to the network that will allow carbon emission reduction without disruption to the existing network. The result of this requirement is that the only coal fired PowerStation has to shut down and that the best way to ensure stability is with active FACTS based compensation.

The Irish Utility installed two 110 kV STATCOM's (Static Synchronous Compensator) using VSC technology on the major 220 kV lines that feeds the wind-energy in the Southwest of Ireland to the major energy distribution hub at Moneypoint PowerStation on the Westcoast of Ireland.

Tough harmonic limits + impedances which leads to C-type filter for the STATCOM, which has low harmonic generation by itself, but amplification was needed for the C-Type filter.

3. Optimal design for substations

A system study was performed by the Irish National TSO to determine the required level of compensation and the level of harmonics present in the Irish transmission system.

A novel / new technology utilised in this is the inclusion of a four frequency active filter that allowed for the reduction of harmonics without the inclusion of the large space requirements of having four passive filters. In this case a **single** frequency passive filter is used to reduce the biggest harmonics of the 3rd order.

In this specific case a 10 Mvar passive filter is utilised to reduce this harmonic. This also has a substantially smaller footprint than having four different C-type passive filters

4. Description of system design of an SVC PLUS station

The MMC technology was described in [1] and its realisation was outlined in [2]. In Figure 3-1 the simplified single line of the Ballynahulla and Ballyvouskill STATCOMs, as well as the ambient harmonics at the PCC are shown.

A typical MMC STATCOM station consists out of a step-down transformer, phase reactors and one or more converters. The converter is built up out of three phase arms which themselves consist of series connected full bridge modules. These consist of a DC-capacitor, IGBT's and diodes and are able to provide positive, negative or zero voltage at their output.

In this project the defined harmonic background voltages combined with the harmonic impedances of the station lead to a very small headroom for allowed harmonic distortions from the STATCOM itself. A multilevel STATCOM itself has very low harmonic generation, but since for some harmonics a damping of background harmonics was necessary, a small C-type filter had to be implemented to keep the required harmonic performance at the PCC.

Additionally, the active filter function of the STATCOM is used to limit the harmonics at the PCC.

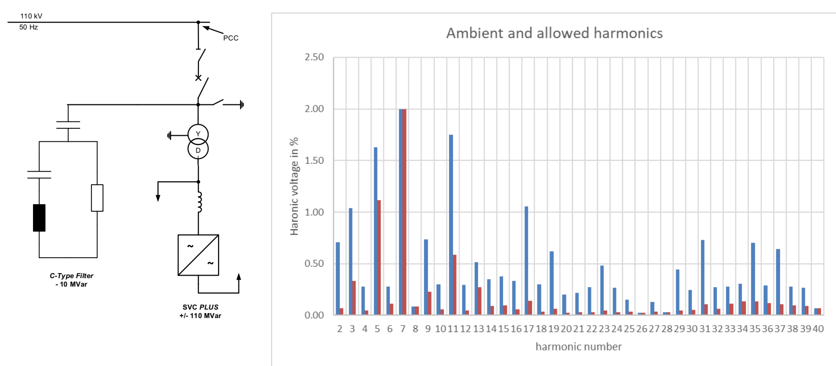


Figure 3-1: Simplified single line of Ballynahulla STATCOM [3]

With a series connection of multiple submodules, it is possible to generate output voltages in different waveforms. This enables the STATCOM to generate defined harmonic currents and therefore to act as active filter. [4,5]

5. Principle of the Active Filter Function

In order to generate a harmonic current, the converter must generate the corresponding harmonic voltage. Figure 3-2 describes the principle of the active filter function. The schematic shows an SVC PLUS between two grids. Grid A has a harmonic source which leads to a voltage with a high harmonic content. The load or grid B has no harmonic source.

Before operation the control gets adjusted to the harmonic impedance. A test signal is generated to evaluate the response of the network to the harmonic signal. This is called Autotuning. The purpose of the autotuning is to adjust the initial response of the active filter to the grid. After that the harmonic controller goes into operation and will compensate the harmonic content of the network.

The active filter has to measure the voltage at the PCC. This voltage is analyzed via a Fast Fourier Transformation to find the harmonic content in the network. With the knowledge of the harmonic voltage content in the network, a harmonic current is generated which will dampen or compensate the harmonic voltage at the PCC, dependent of the strength of the harmonic source.

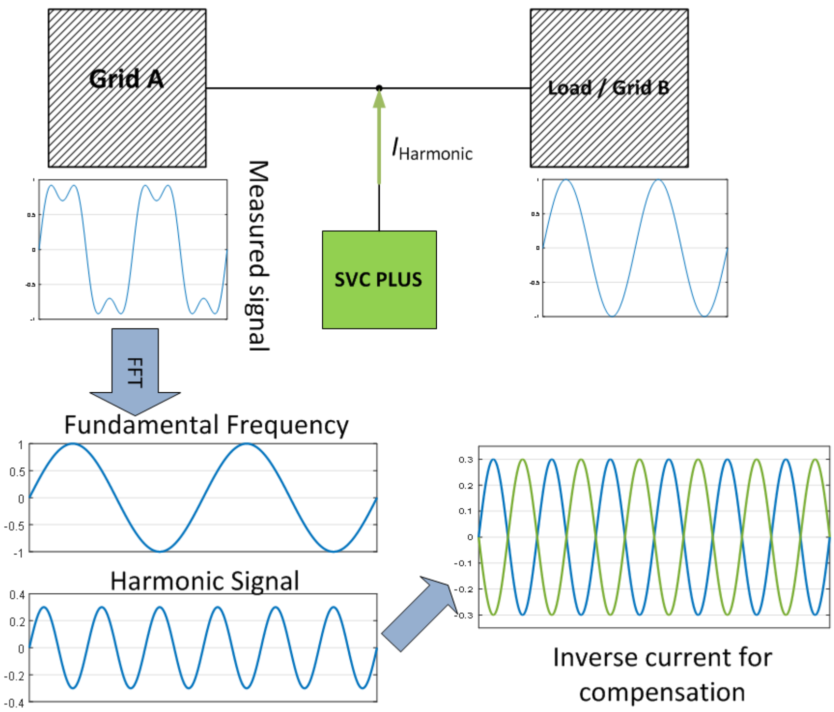


Figure 3-2: Principle of active harmonic filtering

The harmonic current can have an influence on equipment in the HV grid, which is not connected at the PCC. The reason there is that the harmonic voltage at the PCC is lowered by injecting current into the grid. This current will flow through the network impedance and therefore lower the harmonic voltage at the PCC. This way components connected at the PCC will see lower harmonic stresses. An example for this is shown in Figure 3-3. On the left side the harmonic voltage for the 5th harmonic is shown, on the right side the harmonic current through a connected C-type filter.

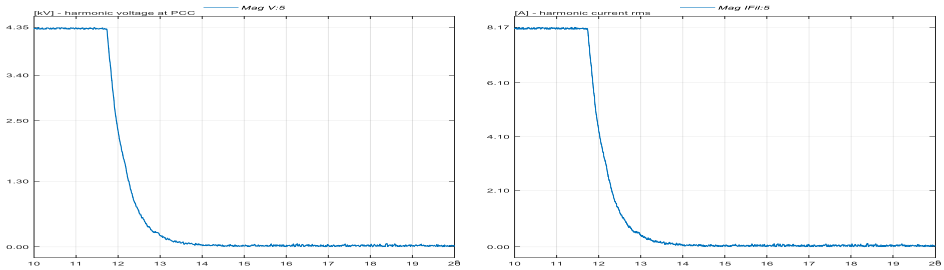


Figure 3-3: Harmoincs at PCC (example for the 5th harmonic)

As can be seen the harmonic voltage at the PCC is compensated by the active filter function, as soon as it as activated. As a result, the harmonic current through the C-type filter is reduced and the stresses for the filter are reduced.

Nevertheless, the harmonic currents will have an impact on the grid and STATCOM components. For the STATCOM this includes the transformer, the phase reactors, the auxiliary equipment as well as the measurement of the voltage. The main impact of the harmonics is the additional stresses to the total thermal rating of the components. The harmonic voltage has to be measured with minimal magnitude and phase error. The exact measurement is crucial for the active filter as wrong measurement could lead to even higher harmonic distortion in the grid.

6. **Studies w.r.t substation factors**, i.e. power requirements, protection mods/ requirements, specialist equipment, footprint or environmental

6.1 Site requirements

With the STATCOMs being installed in energised substations, construction had to be performed in property adjacent to the substation and the availability of real estate a premium, the size of the STATCOM had to be minimised.

Further studies had to be performed to ensure that environmental impact like noise, which is a major issue for local residents, be minimised or reduced to an acceptable level in line with international requirements like IEC. With a transformer connecting the MV side of the STATCOM to the 110 kV Network, the transformer had to be bunded to ensure environmental protection agency guidelines are also met.

6.2 Protection modifications and other requirements.

As the STATCOM needs to be able to operate as a standalone unit the only modifications to the existing substation was the addition of a trip signal to the STATCOM from the 110 kV station. The STATCCOM operates with its own protection devices, all with full redundancy. In the case of any faults, the STATCOM will issue a trip signal to the main 110 kV breaker within the 110 kV substation.

A further addition, but not changing anything in the substation or STATCOM is the addition of an Engineering PC. The purpose of this is to provide remote interrogation ability. This allows for condition monitoring, state of alarms and other information, but absolutely no control functions to ensure Cybersecurity regulations are met.

6.3 STATCOM operation and operational curves

A STATCOM is a fast-acting electronic controlled device capable of providing or absorbing reactive current and thereby regulating the voltage at the PCC to the transmission system. It is categorised as a FACTS devices. The technology is based on VSC's utilising IGBT's. Size of equipment footprint in the substation would dépends on the power rating.

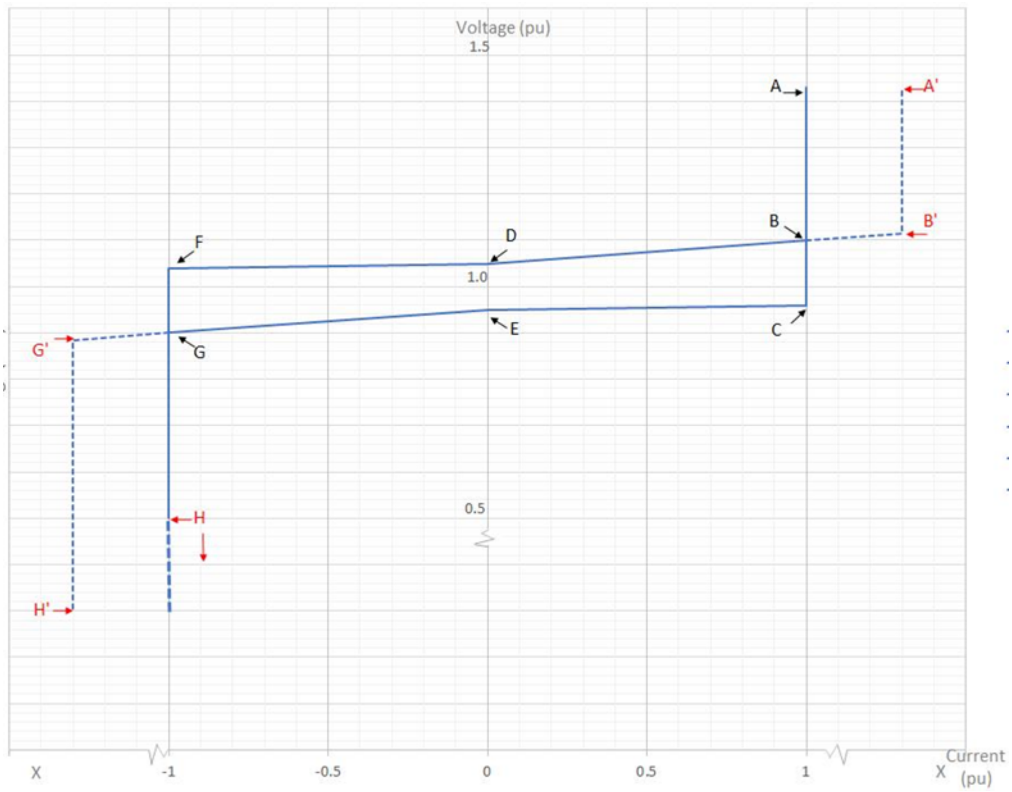


Figure 6.3, STATCOM operating characteristic Illustration only (not to scale)

6.4 Power requirements

The design had to include fully redundant backup power including DC supplies and chargers. Startup occurs from the 110 kV station and then automatically switches over to the STATCOM house transformer with a separate diesel generator as backup.

All these also had to be included in the STATCOM station layout.

As the STATCOM utilize IGBT's operating at high power it requires cooling which affects the power requirements as well, as the cooling has to be operational at all times, including redundancy.

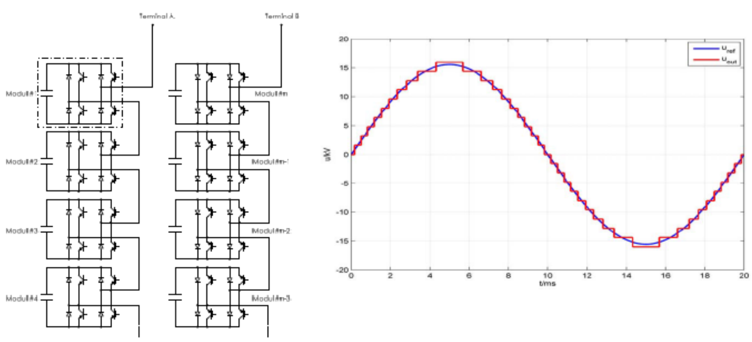
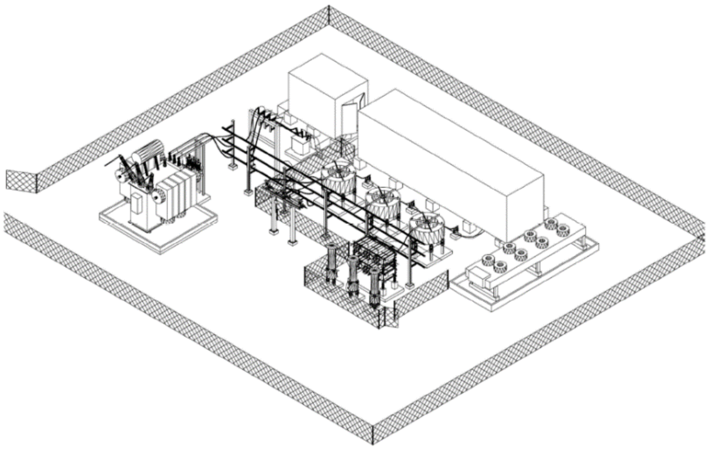


Figure above shows MMC topology. And figure below the basic layout including cooling and all equipment.



7. Testing

All initial testing of the four frequency active filter and protection panels were witness tested in the factory and any changes required were done on the units and software while in factory thus ensuring that the installation on site is so much quicker and smooth in setup.

8. Conclusion

Utilisation of FACTS instead of pure passive filters in the reduction of harmonics is beneficial in reducing substation layout and have the benefit that when circumstances of harmonic levels or different harmonic orders become prevalent, that it would not require major equipment changes to change the active filtering setup.

The STATCOM is a FACTS device that gives the instantaneous reactive compensation and provides the necessary stability on a system that is subject to the ups and downs of renewable energy like wind that have no consistency.

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