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MARINE ACCIDENT INVESTIGATION BRANCH

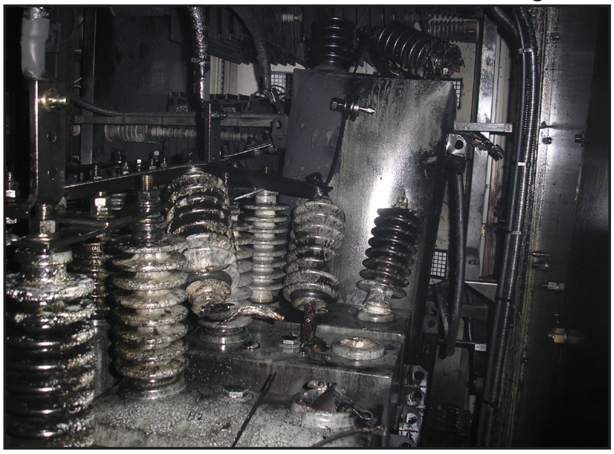
FLYER TO THE SHIPPING INDUSTRY

RMS Queen Mary 2: The catastrophic failure of a capacitor and explosion in the aft harmonic filter room

At 0425 on 23 September 2010, as the passenger liner *RMS Queen Mary 2* (*QM2*) was approaching Barcelona, a loud explosion was heard from the direction of the aft main switchboard (MSB) room. Within a few seconds, all four of the podded propulsion motors shut down. A few seconds later, the vessel suffered an electrical blackout. Thick black smoke was seen to be coming from the aft MSB room. Fortunately, the vessel was clear of navigational hazards and no one was injured.

By 0439, the crew had confirmed that the explosion had taken place in the aft harmonic filter[1] (HF) which was situated in a compartment next to the aft MSB room. After establishing with thermal imaging cameras that there were no hot spots, they ventilated the area and isolated the aft HF and MSB from the rest of the 11000 volt electrical network.The crew were able to restore some electrical power supplies and, by 0523, *QM2* was underway using two propulsion motors powered from the forward MSB. Subsequent inspection of the aft HF revealed that one of its capacitors **(Figure 1)** had failed catastrophically due to internal over-pressure and another had developed a severe bulge.

Figure 1



Harmonic filter capacitors

The vessel had a history of HF capacitor failures, at an average rate of one per year. Although the exact cause of the capacitor failures could not be determined, it was concluded that capacitor degradation was probably caused by a combination of transient high voltage spikes due to frequent switching operations and occasional network overvoltage fluctuations. The capacitor deterioration had not been detected, and because there were no internal fuses or pressure relief devices, it had continued until the capacitor casing failed catastrophically.

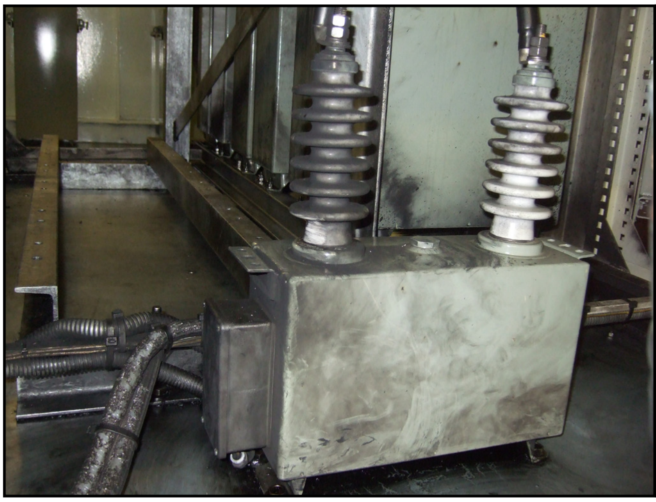
Although the aft HF circuit breaker disconnected the HF from the rest of the electrical network to isolate the electrical fault, the disruption was likely to have caused electrical instability in the electrical network which led to the loss of propulsion and blackout. The vessel's alarm logs were found to contain early warnings about the impending failure approximately 36 minutes before the accident. However, as the vessel's alarm systems regularly logged more than one alarm every minute, this information was not seen and could not be acted upon.

Current imbalance detection system (EstaSym 3C by Vishay Electronics GmbH)

The only protection against catastrophic failure of the capacitors was a current imbalance detection system. It consisted of a current transformer **(Figure 2a)** which was connected to the capacitor circuit. Under normal conditions, little or no current should have flowed through the transformer. When a capacitor degraded, the current flow across the circuit became unbalanced and induced a current in the transformer's secondary winding. The system was set to give an alarm when the imbalance reached 400mA and to trip at 800mA.After the accident, the transformer's windings were found to have failed **(Figure 2b)**. There had not been any alarms on this part of the system for several years and it was likely that the imbalance detection system had not worked for some time.

[1] Harmonic filter: Alternating current (AC) motors for electric propulsion operate on variable frequency and voltage. Thyristors used in the power converters result in voltage distortion. Passive harmonic filters mitigate the effects of excessive voltage distortion.

Figure 2a



The current transformer used in imbalance current detection system

Figure 2b

Damaged transformer windings

This caused the alarm display to read 0mA giving a false indication that the capacitors were in good condition.

Although detection of an unbalanced current was the only protection system for the harmonic filters, it had no backup and did not fail safe. Routine tests of the system were by the secondary current injection method, and by-passed the transformer.

SAFETY LESSONS

- Protection systems for critical equipment must ‘fail safe’, and should be thoroughly tested at regular intervals to prove that all sub-components are functioning correctly. **In particular, harmonic filters with current imbalance protection systems should be thoroughly checked by a competent person at the earliest opportunity.**
- Awareness of the damaging effects of harmonic distortion needs to improve throughout the marine industry as the risks to equipment caused by harmonic distortion are likely to increase significantly as variable speed AC electric motors become more widely used in ships.
- Regular monitoring of electrical networks should be undertaken to provide early warning of deterioration. Monitoring equipment should be capable of detecting transient voltage spikes, resonances, and excessive harmonic distortion levels (either continuously or periodically).
- Procedures need to be established to manage distortion levels in the event that power conversion equipment or harmonic mitigating equipment fails.
- Machinery alarms should be regularly reviewed and prioritised so that the risk of the watchkeeper being overloaded with too many alarms and not notice those from critical systems can be minimized.

This flyer and the MAIB’s investigation report are posted on our website: www.maib.gov.uk

For all enquiries:

Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
SO15 2JU

Tel: 023 8039 5500
Fax: 023 8023 2459
Email: maib@dft.gsi.gov.uk

Marine Accident Investigation Branch
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