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Marsh Risk Management Research

CLAIMS PERSPECTIVE

COMMON CAUSES OF LARGE LOSSES IN THE GLOBAL POWER INDUSTRY

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CONTENTS

INTRODUCTION

Drawing upon the many large losses that Marsh has helped to manage since 2004, this report provides insight into the causes — and monetary value — of large losses in the global power industry.

Throughout the course of this study, data was gathered on all power accounts handled by Bowring Marsh, Marsh's wholesale international placement division, in London. The information presented herein represents 150 claims that have incurred a net loss of more than US$2 million to insurers, net of any applicable deductible, excess, or retention.

While this report is based upon claims that have arisen from the power accounts handled by Bowring Marsh, the large number of clients included in this database allows us to conclude that the losses are generally representative of the sector as a whole. (Note: At the time of printing, some of the claims used in this report were still open, so there may be slight variations when compared to eventual settlement values.)

The period of 2004 to 2012 was chosen to help ensure that only the most modern types of equipment and more recent and relevant risk management practices are covered.

Along with delivering insight into the causes and value of large losses in the global power industry, this report aims to help organizations improve their risk management controls by offering practical guidance on risk mitigation in each relevant area.

The power generation industry, with its sizeable, fixed long-lifespan assets, has not been immune to climate-related challenges.

KEY LOSS CAUSES

Broadly, the majority of operational power generation losses can be attributed to one or a combination of these issues: location, technology, and maintenance.

LOCATION

With climate change and the effects of greenhouse gas emissions high on the social and political agenda and the increased frequency of "100-year" events, weather-related catastrophes are taking a significant personal and commercial toll worldwide. The power generation industry, with its sizeable, fixed long-lifespan assets, has not been immune to climate-related challenges. Floods, in particular, affecting plants either directly or more likely their suppliers, as well as windstorms affecting substations and transmission and distribution (T&D), are likely to account for a significant proportion of the losses sustained.

It should be noted, however, that in practice, power generation plants have traditionally fared quite well with catastrophe events compared to similarly sized property risks. For example, plant damage during the recent New Zealand earthquakes and Australian flooding was minimal, mostly due to the resilience of the facilities' foundations.

Besides the obvious perils of natural events such as firestorms, floods, and windstorms affecting plant and customers/suppliers, areas particularly at risk from location issues include:

1. Plants sited in marine areas, which are vulnerable to increased salinity, with depositing and corrosion risks rising accordingly.

2. Hydroelectric, conventional, and nuclear generation facilities, which are especially vulnerable to droughts. One notable occurrence was the 2003 European heat wave, where producers had to limit — and in some cases suspend — generation at nuclear plants due to river temperatures, forcing them to purchase power at spot-market prices.

WINDSTORMS

In 2005, US windstorms required the replacement of more than 70,000 miles of T&D circuits and lines. In addition to hitting power facilities directly, weather events also have a strong influence on customer demand. Conveniences such as air conditioning can substantially impact residential power usage, which also affects spot-market prices. At the same time, higher air temperatures may adversely affect the efficiency of T&D methods. Seasonality is clearly an issue that needs to be considered and provisioned for by ensuring adequate generation facilities are in place to cope with any reduction in transmission efficiency.

In 2012, Superstorm Sandy made landfall in the Northeast US, severely affecting numerous utilities and generation facilities. Initial estimates of insured damage to these properties was around US$1 billion — however, final adjusted loss amounts will vary from this number.

Insurers have been running catastrophe (CAT) modeling systems for a number of years. With the introduction of RMS 11 in 2011, some cutback in writing was seen from certain insurers in this region due to rate inadequacy, coupled with generous CAT limits and no specific deductibles.

Some of the utilities affected by Superstorm Sandy had renewed their property programs by the end of the second quarter of 2012. Renewal results varied, but all saw a decrease in limits offered for wind, flood, and storm surge, coupled with premium increases that at least doubled. Percentage deductibles were also applied — or a sizeable dollar deductible was added. There was also a renewed focus on CAT definitions and the application of sublimits.

The success of these renewals largely hinged on the lengths to which insureds went to describe the events leading up to the storm, the effectiveness of their contingency planning, and their efforts to strengthen their systems and protect their assets or thereby mitigate recurrence of damage in future storms.

WILDFIRE/BUSHFIRE

Power assets in certain territories around the world are also exposed to the risk of wildfire or bushfire. Although instances of direct damage to power plants have not been seen, exposed fuel sources such as open-cut coal mines are placed on high alert when nearby bushfires present a risk of a flying ember attack.

Distribution systems, however, are directly exposed and bushfires in recent years have caused significant damage to these networks. Transmission lines can be exposed to a different outage risk whereby smoke surrounding high-voltage lines can become ionized and trip the system. History shows that third-party liability exposure associated with wildfire is a significant risk for lines companies, particularly in parts of the US and Australia.

MANAGING THE RISK

Organizations should consider the following steps to address exposures associated with the location of any existing or planned power plant:

1. Undertake a robust geotechnical survey, specifically designed to address environmental/natural catastrophe exposures that are relevant to the location in which the company operates. This step should assist organizations in mitigating disasters such as flood, fire, or earthquake.

2. Evaluate risks derived from working with third parties and explicitly seek reassurance as to the efficacy of partners' approaches to risk management.

3. Conduct a detailed geopolitical survey to fully understand political risks and associated security exposures.

High-temperature components, which are more susceptible to creep-fatigue interaction, are particularly vulnerable.

TECHNOLOGY

TRANSMISSION AND DISTRIBUTION (T&D)

Difficulties have arisen as a result of the increased use of renewable sources, particularly wind and solar. The volatility of supply from these sources may result in blackouts from undersupply or, in the case of oversupply, grid instabilities.

The majority of industrialized nations have, to varying degrees, embraced the trend of privatization of electricity generation and supply. The ensuing separation of T&D from power generation has led to a divorce of responsibilities and created obvious challenges around incentives to invest heavily in power infrastructure projects. The clear failure of regulatory systems to give adequate and reliable price and investment signals dominates the list of reasons why this is an increasingly serious issue.

Subsidy programs such as PROINFA in Brazil, which aims to promote renewable energy and diversifying methods of production, have provided some certainty of guaranteed purchase prices. By contrast, the uncertain state of affairs regarding preferred fuel use in the UK has meant any measures enacted have not adequately met the challenge of rapidly aging substations and power lines. Meanwhile, in Pakistan, the International Monetary Fund is arguing that power-sector reforms are necessary and that certain power subsidies be phased out over the next few years. Similar trends exist in Spain, Italy, Germany, the UK, and many other major markets. The result of these regulatory system shortcomings is uncertainty — the biggest disincentive to investors.

GENERATION

Changes in the daily power generation mix have resulted in an increased reliance on unit cycling as opposed to base-load generation. This change in usage has, in many cases, led to additional thermal and pressure stresses on boilers, steam lines, turbines, and auxiliary components originally designed primarily for base-load generation. High-temperature components, which are more susceptible to creep-fatigue interaction, are particularly vulnerable.

Uneven distribution of heat and unexpected problems with new materials can also arise with newer designs. Concerns over adequate testing of new technologies by original equipment manufacturers (OEM) are clearly well-founded in view of the overhead costs involved. Validating and testing new designs will ideally involve replicating the likely operating and demand conditions, which is an extremely expensive process.

DISPARATE POSITIONS ON NUCLEAR POWER

As if challenges around the rising demand for electricity, the price and reliability of fuel supplies, and the lack of consistent generation from intermittent renewable sources do not present enough uncertainty, popular fear of nuclear power generation — together with concerns over hazardous waste storage and the high costs of decommissioning — has led to a polarization of viewpoints and varied and confusing stances among different countries.

EASTERN EUROPE: Countries including Poland, Czech Republic, Slovakia, Romania, Bulgaria, and Belarus all have plans to develop new nuclear power capacity.

TURKEY: Has already signed one contract with Russia to develop a new nuclear plant and has plans for a second one.

GERMANY: Production at reactors to be stopped by 2023.

SAUDI ARABIA: Extensive construction projects are under way to build multiple nuclear reactors.

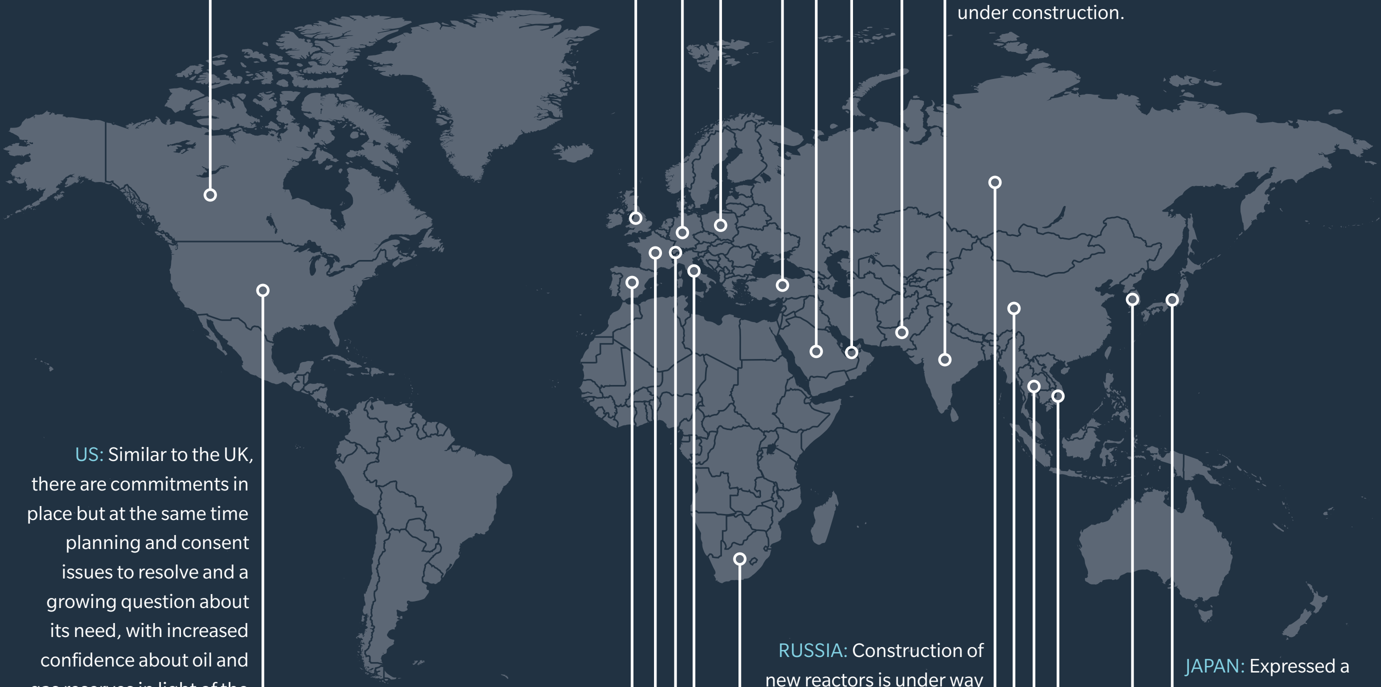
UK: The UK government is committed to new nuclear power, with EDF of France the furthest advanced with its plans for two new reactors.

UNITED ARAB EMIRATES: The UAE's plans for nuclear power are on schedule with unit four of four KEPCO-built reactors on schedule for commercial operation by 2017.

CANADA: A 2012 Canadian Nuclear Association poll found that more than 50% of respondents were opposed to nuclear power. Shortly after this poll was concluded, a license to prepare a site for a nuclear power plant project was granted to Ontario Power Generation.

PAKISTAN: Partnering with China to develop its nuclear industry.

INDIA: Has ambitious plans to develop new nuclear power with seven reactors already under construction.



US: Similar to the UK, there are commitments in place but at the same time planning and consent issues to resolve and a growing question about its need, with increased confidence about oil and gas reserves in light of the fracking uptick.

RUSSIA: Construction of new reactors is under way to boost current nuclear capacity by 50% by 2020.

JAPAN: Expressed a desire to reduce its dependence on nuclear power.

SPAIN: Construction of new reactors banned.

FRANCE: Enthusiasm for nuclear power remains largely unabated.

CHINA: Has the most ambitious plans with approximately 30 reactors under construction today and many more planned.

SOUTH KOREA: In construction and planned, it will see a total of eight advanced PWR1400 reactors become commercially operational by 2021.

SWITZERLAND: Construction of new reactors banned.

THAILAND: Expressed a desire to reduce its dependence on nuclear power.

ITALY: Referendum on nuclear power generation resulted in a "no" vote.

SOUTH AFRICA: Government still plans to have approximately 10,000MWs of operational nuclear power in place by 2030.

VIETNAM: Plans are in place with Russia and Japan to develop two nuclear plants.

Further complications may arise from the individual conditions affecting generation facilities. Locating a plant near the sea might be ideal for cooling purposes, but the increased salinity also exposes machinery to a higher risk of corrosion.

While conventional wisdom would hold that a single large transformer is more efficient than two smaller ones, the maxim might not hold true in remote locations. Shutdown of the single transformer on site will obviously lead to a complete loss of generation, as opposed to only a partial loss if others are on site.

Having spares readily available at alternate sites or from the OEM will not be a guaranteed panacea, given the potential logistical challenges such as government permit requirements, seasonal variances, and poor infrastructure, not to mention the prospect of transporting a fragile piece of equipment weighing several tons. Though not guaranteed, having two transformers is overwhelmingly viewed as the preferred option given the choices available, with bilateral agreements between other plant owners also helpful in mitigating the difficulty of obtaining spares during an emergency.

Increased fuel prices and environmental considerations are also key drivers of efficiency. The push for efficiency invariably involves using new techniques, technologies, and materials to reduce fuel costs and carbon dioxide emissions. To put the position into perspective, an increase of 50°C in the firing temperature of a turbine will increase thermal efficiency by around 3% and overall output by around 10%. There is, therefore, great pressure on equipment manufacturers seeking to market the most efficient model to maximize tolerances to produce the highest megawatt/dollar ratio — with attendant risks clearly arising as a result.

The price of high-specification materials may include decreased corrosion protection with an accompanying increase in susceptibility and reduction in tolerance. Other areas of possible concern with new designs include rotating parts being affected by the twin perils of greater thermal elongation from higher temperatures and smaller tolerances. Increasing market demand for faster-start turbines to cope with peak demand — for example, the recent introduction of simple cycle turbines capable of 10-minute starts — will only further exacerbate these issues.

Current goals of moving into the ultra-supercritical realm (loosely defined here as greater than 650°C or greater than 275 bar main steam pressure) indicate that the drive for efficiency and the demands on equipment manufacturers are unlikely to abate or conclude in the near future.

MANAGING THE RISK

Organizations should consider the following steps to address exposures associated with the technology of any existing or planned power plant:

1. Develop and refine operating and maintenance policies and philosophies to achieve best practice.

2. Maintain relationships with OEMs, user groups, and other industry sources for a better understanding of technical issues and loss experience.

Despite the perspective that a company that suffers a loss must act as “a prudent uninsured,” it inevitability remains the case that smaller — often one-plant — operations will have insufficient funds to meet the repair costs demanded by contractors and OEMs without swift financial support from insurers. While a major producer suffers financial discomfort from losing the ability to generate at a given plant, a total disruption of 100% of the insured’s one-plant business is a devastating blow that could threaten financial stability. This is particularly the case if, for example, the disruption of a waste-burning plant incurs additional costs for transferring the contracted waste to landfill sites. In this case, a strong claims presentation and expertise to establish coverage and ensure at least interim payments as soon as possible post-loss are essential.

OPERATIONS AND MAINTENANCE

Much of the fleet of power generation and T&D equipment currently in service is, by original design standards, due for replacement in the next few years, if not sooner. Due to closures and a decline in investment for new plants, there is an increasing trend towards extending the life of conventional plant. This includes thermal and nuclear power plants that are now obtaining extended operating licenses.

In 2011, nearly 300 nuclear reactors were at least 25 years old; less than 50 new units were added to the generation network in the previous decade. Due to the lack of new facilities, operators of more than 70 reactors in the US alone have obtained 20-year extensions. With adequate licensing, operating lifetimes of 60 or even 80 years are increasingly becoming both likely and necessary.

Additionally, where long-term service agreements (LTSA) with conventional plants apply, OEMs are likely to ensure a priority of service and expert assistance, maintenance, and adequate operator training. These elements are vital when working with heavy machinery for several reasons:

- **Performance:** Preventative maintenance reduces the likelihood of breakdown and increases the possibility of identifying and using either backup or alternate sources of generation.

- **Safety:** Unit failure is a clear risk both to personnel at the plant itself and to those who rely on the power for their daily needs. A proper maintenance program should be able to effectively identify any component issues before a failure occurs.

- **Reliability:** While vital systems such as hospitals are likely to have backup power sources, a failure to supply enough power to the grid may lead to blackouts. Recent events in 2013 in Panama and Pakistan have shown the level of disruption and resulting bad publicity that can arise from such events.

- **Economics:** Pre-failure replacement of components will result in shorter outages and maintenance downtime, particularly if standby systems also fail to operate.

Preventative maintenance reduces the likelihood of breakdown and increases the possibility of identifying and using either backup or alternate sources of generation.

Poor fuel quality is of particular concern to power generation operators.

Particular vulnerabilities that arise include high- and low-cycle fatigue, corrosion, oxidation, thermal mechanical fatigue, rubbing/wearing, and creep fatigue. For machinery, especially turbines, factoring in the correct starting cycle, power setting, and fuel and steam/water injection is vital when determining maintenance requirements for critical components.

Although transformers are continually subject to chemical, thermal, electromagnetic, mechanical, and electrical stresses while under load conditions, a suitable maintenance program incorporating adequate dissolved-gas analysis can, in many cases, detect and resolve potential symptoms of failure.

Poor fuel quality is of particular concern to power generation operators. Ensuring the correct balance of substances, notably in waste facilities, may require additional fuel to be added to the refuse that is being burned to ensure proper burning. Such an addition is vital to ensure both consistent generation and compliance with emission requirements. Careful monitoring of fuel types to ensure sufficient purity is critical, and adhering to OEM requirements is often a condition of claims coverage or, in some cases, even a warranty that could affect an insurance policy.

Gas turbine performance and lifespan, especially the hot gas path elements, are vulnerable to trace metal contaminants from air inlets, fuel, and injected water/steam. Proper control of such contaminants is vital, notably those trace metals found in heavier hydrocarbon fuels such as lead, potassium, vanadium, and sodium, as well as other contaminants such as calcium, in order to avoid blade corrosion in turbines and the build-up of deposits in machinery.

Conversely, the compressor side of the gas turbines is extremely vulnerable to atmospheric conditions in, for instance, saline environments or heavy industrial environments, and air filtration systems need to be adapted for the site.

Fuel oil can also be contaminated by salt water, notably ballast, mixing with cargo during transport, impurities entering the fuel during road/rail transport, or via non-dedicated pipelines. Proper fuel specification should be required from suppliers, and fuel treatment, quality checks, and maintenance should be routinely performed.

MANAGING THE RISK

Organizations should consider the following steps to address exposures associated with the ongoing maintenance of any existing or planned power plant:

1. Build crisis management and recovery plans in conjunction with third parties to improve response planning and resilience to an incident.

2. Invest in high-quality operations and maintenance partners, and work with them to implement robust staff recruitment drives, followed by quality training and development programs to ensure employees are highly engaged and trained.

3. Implement a thorough operations and maintenance strategy, including shut-down protocols, best-practice condition monitoring of critical equipment, and proactive root-cause analysis (RCA) investigations.

4. Ensure all possible fire prevention and protection procedures are in place to safeguard critical equipment and staff, based on industry best practice and international standards.

The requirement to undertake a full RCA may involve the transfer of machinery to a specialist workshop, which may be hundreds or thousands of miles from the site. Moving equipment of this scale is difficult, neither quick nor cheap, and may require additional insurance to cover the transportation to and from the workshop, the stay in the workshop, and any eventual additional loss of revenues.

The ability to obtain spare parts, particularly for bespoke machinery, is a key consideration. It is notable that, with the speed of technological innovation, obtaining spare parts for machinery that is only a few years old can also prove to be troublesome. This is already the case for instance with Generation 1 and 2 wind turbine generators, where spare parts can sometimes only be sourced from decommissioned machinery.

Much of this equipment is now reaching the end of its design life. Significant downtime, with losses that are both insured and uninsured, is the inevitable result if spares cannot be obtained and transported to site quickly — particularly if the loss occurred during a period of high demand. The availability of spares can vary with market conditions. A few years ago, when there were a large number of new projects, lead times for spares increased dramatically, though they seem to have fallen since then.

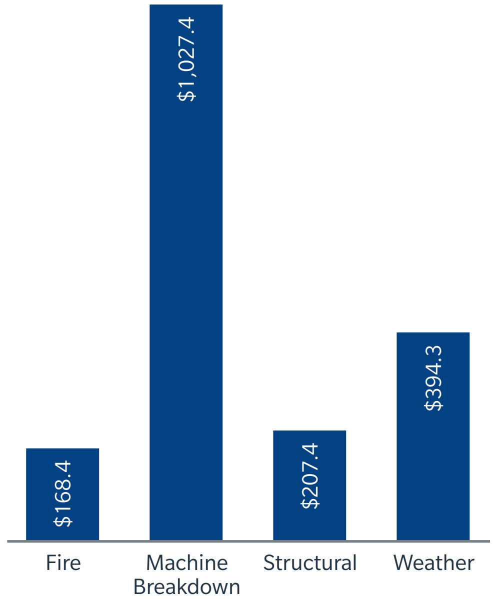
RECENT LOSS CAUSES

This section draws on 150 operational insurance claims that Marsh has helped to manage since 2005. These losses total more than US$1.8 billion — a figure that includes both settled losses and reserves for losses that remain ongoing. These losses reflect a range of different causes, with some clear patterns emerging.

In total, losses attributed to weather events, fire, or machinery breakdown account for more than 95% of the 150 losses used in this analysis (see Figure 1). Machinery breakdown losses dominate in terms of the number of instances (76%).

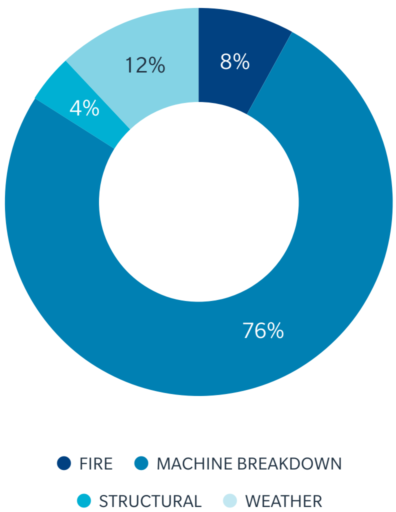
An interesting trend emerges when each cause is broken down in terms of US dollars (see Figure 2). While machinery breakdown makes up more than three-quarters of the total number of losses, its importance is considerably reduced when US-dollar value is used as the basis of measurement. Only 57% of the total US dollar costs was attributable to machinery breakdown.

FIGURE 2: VALUE OF LOSS BY TYPE (US$ MILLIONS)



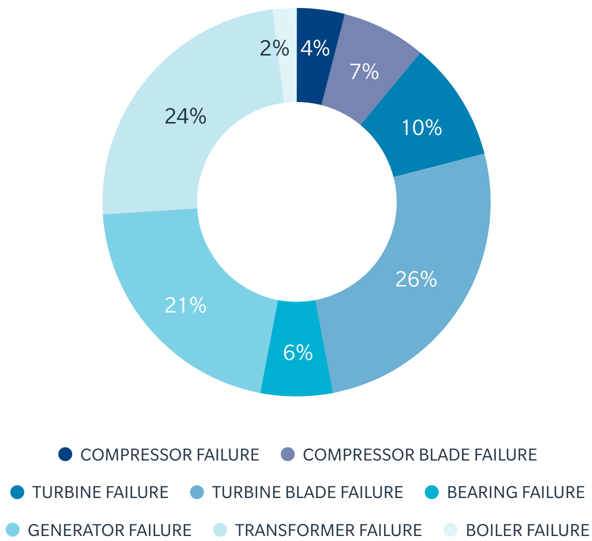
Source: Bowring Marsh

FIGURE 1: TYPES OF LOSS BY PERCENTAGE



Source: Bowring Marsh

FIGURE 3: MACHINERY BREAKDOWN BY FAILURE



Source: Bowring Marsh

Weather-related events, while comparatively rare at only 12% of the losses sustained, accounted for 22% of the total cost in US dollars. Structural losses, including collapses, also demonstrate a sizeable per-event impact — only 4% of the total number of losses but 11% of the total dollar value.

In Figure 3, machinery breakdown is divided by its cause. Failure of turbine blades, transformers, and generators clearly dominate the list of machinery breakdowns, comprising 77 of the 108 machinery breakdown losses (71%). Non-blade-related turbine losses are responsible for almost 10% of the remaining portion, making turbines a clear and essential target for effective risk management controls.

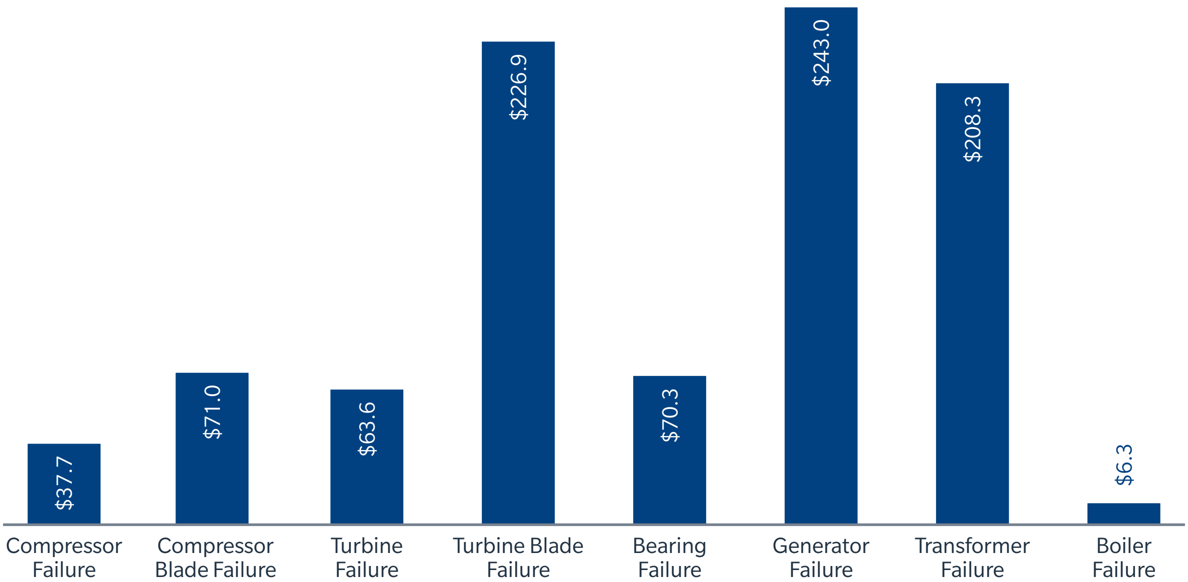
Machinery breakdown, when assessed by US dollars, also shows some disparity compared to the number of losses (see Figure 4). While the proportions change a little when US dollar amounts are taken into account, turbine blades, transformers, and generators still dominate.

SUMMARY OBSERVATIONS

All types of commercial and industrial locations have proven vulnerable to weather-related events — it's not just a risk that predominantly affects the power industry. While weather-related impacts are subject to only limited forms of control — for example, situating control rooms on upper floors to avoid flooding and sourcing alternate supply chains for essential products — both technology and maintenance risks can be, and often are, more thoroughly managed.

Stressing the value of monitoring and controlling the technology employed, notably for reliability as well as efficiency, and ensuring a proper program of maintenance are clearly critical components of loss prevention. In turn, loss prevention is essential for ensuring reputation, operating efficiency, and reduced premium rates.

FIGURE 4: VALUE OF MACHINERY LOSS BY TYPE (US$ MILLIONS)



Source: Bowring Marsh

ABOUT MARSH

Marsh is a global leader in insurance broking and risk management. We help clients succeed by defining, designing, and delivering innovative industry-specific solutions that help them effectively manage risk. We have approximately 26,000 colleagues working together to serve clients in more than 100 countries. Marsh is a wholly owned subsidiary of Marsh & McLennan Companies (NYSE: MMC), a global team of professional services companies offering clients advice and solutions in the areas of risk, strategy, and human capital. With more than 53,000 employees worldwide and annual revenue exceeding $11 billion, Marsh & McLennan Companies is also the parent company of Guy Carpenter, a global leader in providing risk and reinsurance intermediary services; Mercer, a global leader in talent, health, retirement, and investment consulting; and Oliver Wyman, a global leader in management consulting. Follow Marsh on Twitter @Marsh_Inc.

ABOUT BOWRING MARSH

Bowring Marsh is the exclusive, specialist international placement broker for Marsh. Working seamlessly with Marsh, Bowring Marsh provides access for clients, wherever they are in the world, to international insurers through its global insurance placement platform.

With more than 270 insurance brokers located across all the major international insurance hubs, Bowring Marsh provides customers with options in the international markets. We drive price and coverage by putting international and domestic insurers into competition against each other and by differentiating our customers' risks, whether they are strategic insurance buyers, claims distressed, exposed to natural catastrophe, or buying large limits due to the nature of their operations.

Placing in excess of US$2.5 billion of premium for more than 1,500 customers annually, we use the breadth and depth of our portfolio experience and industry knowledge to innovate, customize, and broker our clients' insurance contracts with international insurers.

ABOUT MARSH'S GLOBAL POWER PRACTICE

Marsh is the globally acknowledged market leader in the provision of insurance and risk management services to the international power and utilities sector. Our global client base encompasses the whole spectrum of power and utilities, including vertically integrated nationalized industries, transmission and distribution companies, independent power projects (IPP), combined heat and power (CHP) projects, combined power and desalination projects, as well as nuclear and renewable energy companies. Water, wastewater management, and gas distribution also come into the category of utilities.

Our industry practice approach provides us with a broad and deep understanding of the particular needs of power and utilities companies — and to tailor our services and solutions accordingly. Services are delivered through a long-established international network of centers of excellence and in-country industry specialists, many of whom have formerly worked in the power industry. These dedicated resources span all relevant disciplines, including client servicing, insurance broking, risk engineering, and risk management for insurable and non-insurable risk, and offer clients dynamic risk assessment, deep market relationships, and bespoke consulting services.

Marsh has a team of power engineering specialists who provide risk assessment reports for insurers and loss prevention advice and opportunities for improvement to clients to achieve best practices.

Through our market relationships, industry knowledge, and program-design capabilities, Marsh and Marsh & McLennan Companies have an unrivaled ability to assist power and utilities companies in ensuring the optimum combination of risk retention, risk control, and risk transfer.

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