Renewable Energy 67 (2014) 143–152

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Sustainable asset integrity management: Strategic imperatives for economic renewable energy generation

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ARTICLE INFO

Article history:
Received 6 October 2013
Accepted 14 November 2013
Available online 27 November 2013

Keywords:
Sustainability
Renewable energy
Asset integrity management
Asset performance
Environmental conservation
Downtime minimization

ABSTRACT

This paper develops a framework for sustainable asset integrity management (AIM) with regards to renewable energy generation plants. The authors conclude that increased downtime, low energy output, high cost of maintenance and repair operations, which are attributable to poor assets integrity management, can be mitigated with sustainable AIM. The enhancement of economic and efficient energy generation in renewable energy plants, therefore, involves a structured procedure that combines socio-economic and environmental demands in decision supports for facilities management. This can be achieved utilizing a function interfaced organizational model and techniques that include mitigation, prevention and regulatory programmes. Environmental conscious planning, review and task execution in AIM are vital to health, safety and environmental conservation whilst improved asset lifecycle performance can be reached through competence, compliance, control, communication and co-operation of management and personnel. In conclusion, proper coordination of AIM through an accurate understanding of the stakeholder demands results in efficient renewable energy generation.

1. Introduction

The need for a green world economy has been the focus of many researchers worldwide with the United Nations Environmental Programme (UNEP) defining a green economy as one that results in improved human wellbeing and social equity, while significantly reducing environmental risk and ecological scarcities [1]. This implies that the world energy consumption can be green provided that environmental considerations accompany their utilization. This scenario is unfortunately not the case with fossil fuel which is one of the world's predominate energy source. The extent of greenhouse gas (GHS) emission by fossil fuel is so significant that there is an urgent need for reducing the carbon footprint of the world via use of alternative energy sources that are benign to the environment. This has led to more interest in renewable energy sources (RES) which have a lower pollution effect when compared to fossil fuel. Research shows that the world's energy need will grow from 12,271 million ton oil equivalent (Mtoe) in 2008 to 18,048 Mtoe in 2035 with an average annual increase of between 1.4% and 3.4% for non-OECD countries and approximately 0.3% for OECD countries [2]. Considering the fact that 81% of the total energy consumed in the world in 2009 was from fossil fuel [3], the current implication of higher world energy demand would be increased pollution together with the associated complexities of fossil fuel utilization [2] should RES not be utilized to bridge the gap.

The major challenges of world energy at the present time include ensuring energy security, combating climate change, reducing pollution based risks to public health and addressing energy poverty [2]. To address these problems require a proactive renewable energy development and utilization policy which according to the Green Energy Report (GER) model will involve a 40 year global investment of $650 billion annually in order to provide a 27% renewable energy supply by 2050 whilst reducing greenhouse gas emissions by 60% [4].

According to a report by Bloomberg New Energy Finance and UNEP, the investment on renewable energy assets around the world grew from $33 billion in 2004 to $211 billion in 2010 [5] as shown in Fig. 1. This continuous investment on generation plants requires proactive steps to maintain the reliability of the assets and ensure economic and efficient energy generation. The aim of this paper is to develop the strategies necessary for managing assets in renewable energy plants in order to ensure that cost is minimized. Outlining the possible challenges of different RES and associated asset failure patterns will also provide experts with more information concerning expected impedances to the establishment of renewable energy plants whilst ensuring asset integrity through minimized maintenance costs.

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0960-1481/$ – see front matter
http://dx.doi.org/10.1016/j.renene.2013.11.024

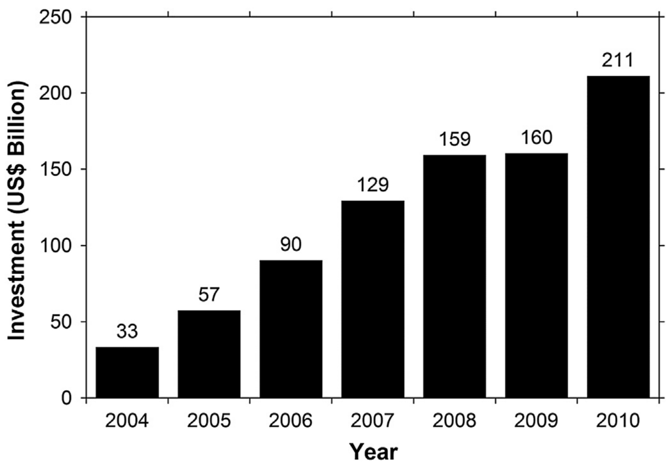

Fig. 1. Global new investment in renewable energy (2004–2010) [5].

1.1. Challenges of renewable energy (RE) plant operation

The establishment and operation of RE generation plants are not without challenges which may be technical, economic, environmental and social in nature. The primary challenge is that the level of development of technologies for the extraction of the RE should not be comparable to that of fossil fuel hence making the cost of energy production unreasonably high [2,6] as shown in Table 1 [6,9–11]. For example, this table illustrates the projected future cost of generating RE to be high in comparison with that of conventional fossil energy sources in US, UK and Australia. However, Owen [7] has argued that should the externality costs of fossil fuel be built into energy generation and tariffs then RE would be more affordable than fossil energy. The return on investment is another major factor influencing investment decisions with Leijon et al. [8] stating that the return on investment for RES should be measured as the rate of energy production since the energy obtained by most RES is not stored but instead transmitted immediately – the real return on investment should therefore be a measure of the utility factor. This outcome of this approach would make the length of time expected to recoup invested capital on RE generation to be longer for those with lower utility factors.

Operation and management of RE plants can be painstaking due to complexities of the operation, cost and environmental concerns [12,13]. For example, data acquisition and condition monitoring can be difficult for plants located offshore and hence data would need to be remotely acquired using the Global Positioning System (GPS), satellites and personal computers with database systems. Servers may also be deployed for operational monitoring and evaluation of incoming field data [14]. One of the crucial drawbacks in the utilization of RE is variation of climatic conditions [12] which makes it imperative that optimization models be used for planning energy generation operations as noted by previous researchers [12,15–17]. Proper planning of inspection and maintenance programmes is also vital in achieving cost savings and efficient energy generation.

The UNEP (2011) report on renewable energy [2] indicated that the cost of RE was becoming increasingly competitive with fossil fuel due to increased research and development (R&D), economies of scale, learning effects through cumulative deployment and increased competition among suppliers – however, further government policy support and implementation was deemed vital. According to Wood and Dow [18], deficiencies in the implementation of renewable energy policy in the United Kingdom were attributed to factors such as: (i) finite and limited duration of subsidies lifespan, (ii) excessive focus on competition and low cost, (iii) unresolved planning and grid network issues and (iv) policy uncertainty/excessive charges. Not only limited to the United Kingdom, such problems have been among the main difficulties associated with effective deployment and use of RES throughout the world.

Table 1
Levelled cost of energy generation for renewable energy compared to other sources [6,9–11].

Plant type	Cost for plants entering service in		
	2017	2015	2015
	(2010 US$/MWh)	(2010 £/MWh)	(2010 AUD$/MWh)
	US[a]	UK[b]	Australia[c]
Coal	99.6		80.67–89.65
Coal with CCS	–	128	135.06–161.53
Advanced coal	112.2		
Advanced coal with CSS	140.7		
Natural gas (NG) fired			
NG: conventional combine cycle	68.6	83	93.57
NG: conventional combine cycle with CCS		95	149.51
NG: advanced combined cycle	65.5		
NG: conventional combustion turbine	92.8		
NG: advanced conventional combustion turbine with CCS	132		
Nuclear	112.7	80–105	133.36
Geothermal	99.6	105–268	71.14–135.53
Biomass	120.2	141–154	99.58
Wind	96.8	88–139	87
Solar PV	156.9–251	228	208.60–438
Hydropower	89.9	59–105	191.81
Wave	–	227–237	208.07–362.13

CCS: Carbon control and sequestration.
[a] Source: US Energy Information Administration [9].
[b] Source: UK department of Energy and Climate Change [6,10].
[c] Source: CSIRO publication, Unlocking Australia's Energy Potential, 2011 [11].

1.2. Geothermal energy

Apart from the cost of generating geothermal energy, water chemistry management is another major challenge that has affected the efficiency of plants around the world [16,19,20] with a summary of different failures encountered in geothermal plants due to water chemistry issues being presented in Table 2.

1.3. Wind energy

The generation of RE from wind energy has become increasingly popular with approximately 3% of energy worldwide being produced from wind energy during 2012 [21]. Among the imminent challenges facing wind energy generation is the high cost of maintenance and operation together with the low efficiency (typically 25%) of the generating plants [22]. A summary of available data for the downtime accrual and failure rates of different wind turbine components has been summarized in Fig. 2 [25,27–29]. Whilst the gearbox component in general has traditionally contributed to the highest downtime [22–24], ageing wind farms have been particularly susceptible to significant failure rates and reduced power output/efficiency of this component. Indeed, research has indicated that the reliability of gearboxes in wind farms is of major concern and relates to the design and manufacturing processes amongst other causes. Musial et al. [24] concluded the gearbox reliability problem to be generic with 10%