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Application of computational intelligence techniques for load shedding in power systems: A review

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ABSTRACT

Recent blackouts around the world question the reliability of conventional and adaptive load shedding techniques in avoiding such power outages. To address this issue, reliable techniques are required to provide fast and accurate load shedding to prevent collapse in the power system. Computational intelligence techniques, due to their robustness and flexibility in dealing with complex non-linear systems, could be an option in addressing this problem. Computational intelligence includes techniques like artificial neural networks, genetic algorithms, fuzzy logic control, adaptive neuro-fuzzy inference system, and particle swarm optimization. Research in these techniques is being undertaken in order to discover means for more efficient and reliable load shedding. This paper provides an overview of these techniques as applied to load shedding in a power system. This paper also compares the advantages of computational intelligence techniques over conventional load shedding techniques. Finally, this paper discusses the limitation of computational intelligence techniques, which restricts their usage in load shedding in real time.

1. Introduction

Over the last decades, the world has witnessed many severe power system blackouts in various continents. These blackouts have affected millions of people, resulting in huge economic loss and social impact over the societies. The social impact of a power blackout, especially in urban areas, is severe – health care facilities in hospitals are affected, traffic control problems lead to accidents, and the Internet and other communications systems break down. The detailed consequences of power blackouts are shown in Fig. 1 [1].

A blackout in a power system refers to the unavailability of electric power in an area for a short or long duration. These power blackouts can occur due to natural reasons as well as technical reasons. Natural reasons include animal contact with a live conductor, a vehicular accident resulting in damaged transmission poles, and trees falling on transmission lines due to stormy weather. Technical reasons include faults, damaged transmission or distribution lines, stability issues, overloaded transmission lines, cascading events, faulty equipment, and human error. The estimated unsupplied energy is another important factor leading to blackouts. Some of these reasons, like faults, are initiating contingencies; others are the subsequent consequences of those events which may result in instability and cascading, leading to a blackout. This paper focuses on those power blackouts which have occurred due to technical failure. The top ten most severe power blackouts that have occurred in the last two decades, affecting millions of people, are shown in Table 1.

Table 1 shows that within this period, Brazil and India suffered a large-scale blackout at least twice, whereas the other countries/regions like Egypt and Europe were hit by a massive blackout only once, in 1990 [2], and in 2006 [6,7], respectively. During these blackouts, 50 million people in Egypt were affected for 6 h, while 15 million people in Europe were affected for 2 h. The blackout in Egypt was characterized by a very rapid voltage collapse to nearly 20 V, followed by sudden total voltage collapse. The severe blackout that occurred in India in 2001 was due to a failure of substations. This blackout affected 226 million people for 12 h and resulted in an overall economic loss of 110 million USD. One of the most significant blackouts occurred in the United States and Canada on 14th August 2003. This blackout affected around 50 million people in eight US states and two Canadian provinces. Estimates show that this blackout interrupted around 63 GW of load, and more than 400 transmission lines and 531 generating units at 261 power plants tripped [4,5,9]. It lasted for 96 h (4 days) in various parts of the eastern United States [10] as shown in Table 1, resulting in an economic loss of approximately 4–6 billion USD

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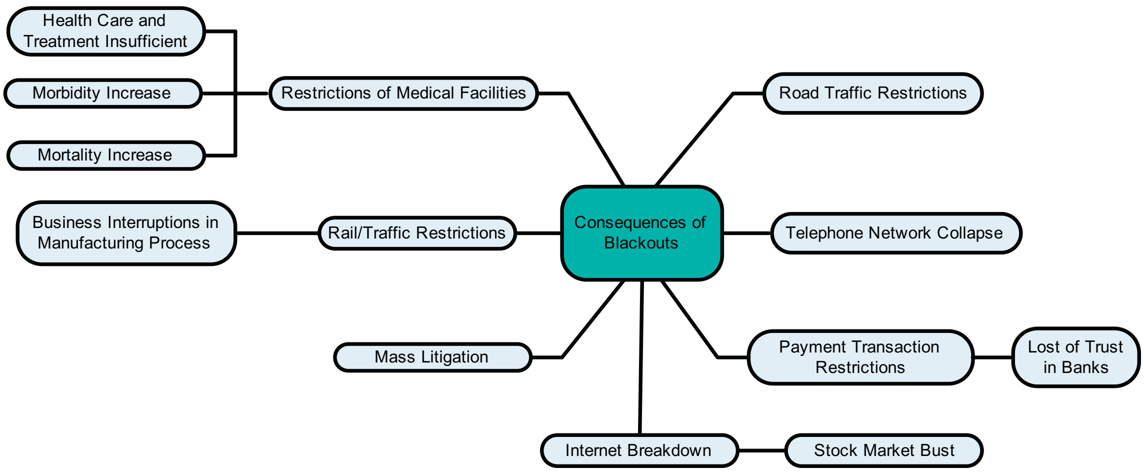

Fig. 1. Consequences of power blackouts.

Table 1
Most severe power blackout in last two decades around the world.

Country	Date	Affected people	Duration	Causes of blackout
Egypt	24th April 1990	50 million [2]	6 h	Voltage collapse
Brazil	11th March 1999	97 million [3]	5 h	Lightning strike causing 440 kV circuits to trip
India	2nd January 2001	226 million [3]	12 h	Transmission line fault
Canada and Northeast United states	14th August 2003	55 million [4,5]	96 h (4 days)	Lack of maintenance, human error and equipment failure
Italy	28th September 2003	56 million [5]	18 h	Tripping of power lines
Indonesia	18th August 2005	100 million [3]	7 h	Transmission line failure
Europe	4th November 2006	15 million [6,7]	2 h	Overloading
Brazil and Paraguay	10th November 2009	87 million [3].	7 h	Short circuit on three transformers on high voltage transmission line
Brazil	4th February 2011	53 million [3]	16 h	Flaw in transmission line
India	31st July 2012	670 million [8]	15 h	Voltage collapse due to overloading of transmission line

[11]. Indonesia suffered a severe blackout in 2005 that affected 100 million people for 7 h [3]. The world's largest blackout happened recently on 31st July 2012 in India following a voltage collapse due to the overloading of transmission lines. It affected around 670 million people, hundreds of trains, and hundreds of thousands of households in 22 Indian states [8].

Apart from these severe blackouts, every country suffers from small power outages many times in a year. Fig. 2 shows the number of power outages that occurred in different parts of the world in 2009; Fig. 3 shows the duration of these power outages. This study was conducted by the Sustainable Development Network of the World Bank Group [12].

Figs. 2 and 3 shows that South Asia had up to 1200 power outages, but these had the shortest duration compared to those in other parts of the world. Latin America and the Caribbean experienced the fewest power outages, but their duration was the longest compared to those in other places. According to an annual report issued by the Eaton Blackout Tracker in 2011, there were 3071 power outages in different states of the US that year, affecting 41.8 million people. The top ten states in the US with the most number of reported power outages in 2011 are shown in Fig. 4.

It can be observed that many developed states in the US, such as Washington, New Jersey, Michigan, Texas, New York, and California, also had a significant number of power outages in 2011 [1].

The most common factor contributing to power blackouts is the voltage instability issue arising from the overloading of the transmission system [2], which may result in a cascading or islanding event leading to a blackout, as in the Egypt and India blackouts. During such conditions, accurate load shedding is crucial to prevent total system collapse. However, improper load shedding has led to a high number of power blackouts due to surplus or insufficient load shed; this has questioned the ability and reliability of

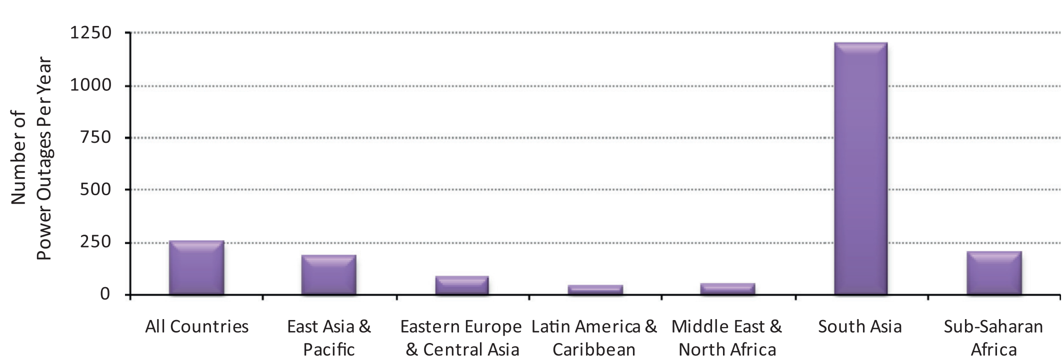

Fig. 2. Number of power outages in different parts of world.