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Literature Review of Power System Blackouts

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Abstract

Blackouts in a power system can occur in several ways. How to prevent a blackout is an important issue in power systems. The reasons to cause blackouts can be the overloading of transmission lines, ice coating on lines, failure of protection or control systems, and others. Blackout can be prevented through appropriate control strategies in a system to prevent from an N-1 contingency, maintain load-generation balance, and cascade to more fault contingencies. This work reviews blackouts from different countries by considering their causes and solutions, as well as the discussion thoughts from many researchers. The survey can provide significant references to improve the grid protection strategies.

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Keywords: Blackout, Power System, Protection, Contingency.

1. Introduction

In recent years, numerous blackouts in the world have been occurred, such as 2003 North American blackout, 2006 European blackout, and 2013 Indian blackout. Those blackouts caused great financial losses and brought inconvenience to people. There are many reasons to cause those blackouts, such as transmission line tripping and overloading, failure of protection or control systems, voltage collapse, cyber attack, and others. The experience learned from those historical blackouts provides significant references to improve the existing power grids. This work reviews the current power system blackouts in the world and investigates the reasons that caused the blackouts. Additionally, this work also proposes several corresponding improvement schemes to avoid power system blackouts.

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The main purpose of this investigation is to obtain potential protective mechanisms against blackouts in power systems, and to help power systems design their prevention plans.

2. Historical blackouts in the world

This section introduces several power system blackouts around the world. The experience learned from those blackouts provides significant references for improving existing power systems. Many power system blackouts have occurred in large power systems, such as the blackout in North America or Europe. On January 24th 2006, a blackout occurred on the Greek island of Kefallonia [1]. The main reason of that accident is the towers collapse and the greatly loads with ice on overhead line conductors. The conductor surface of the high-voltage tower was coated with an ice-sleeve approximately 15 cm in diameter. The consequences of the blackout caused the cut of electricity by approximately 3000 MWh. Since the blackout occurred, additional substations have been commissioned in Kefallonia Island. Additionally, the distance between towers has been re-established to endure the climate changes. New and existing lines have been upgraded and derived into several anti-icing methods.

On August 13th 2003, a cascade blackout occurred throughout Ohio, Michigan, Pennsylvania, New York, Vermont, Massachusetts, Connecticut, New Jersey, and Ontario, Canada [2]. The blackout of 61,800 MW lost lasted around 4 to 7 days before the power fully restored, which affected around 50 million people. During the observation of the blackout, several key causes had been identified. For instance, the state estimator (SE) and contingency analysis of the Midwest ISO's (MISO) were not under full automatic operation; they did not solve line outage effectively. Additionally, the managements of load rising, increasingly limited generation, and reactive power imbalance were inadequate at MISO. Inadequate Tree Trimming also causes this blackout; as long as the trees around the high-voltage conductors are trimmed to a certain distance, short circuit could be avoided. After this accident, the traditional network has been upgraded using smart grid's technologies. The traditional power systems used system control and data acquisition (SCADA) systems. However, SCADA systems cannot provide the view on the whole system; moreover, the coordination for transmission is extremely slow and the system communications is based on telephone calls. By contrast, the smart gird technologies provide advanced communication, monitoring, pervasive control and digitalized systems. Notably, even though smart grids provide better control and monitoring systems, the cyber-security brings the challenge to system operators.

One of the blackouts in the Indian recently is on July 30th and 31st 2012, two blackouts occurred and lasted several hours causing over 620 and 700 million people, respectively, with the electricity lost. The first blackout was caused by an overloading event that happened on the 400 KV Gwalior-Bina transmission double lines (one of the double lines was under maintenance). Therefore, the overloading caused a cascade of tripping through the network, leading to approximately 32 GW of generation shortage. Due the higher demand with the lack of generation and the inadequate response to the issue, the system failed again on 31st of July. The reasons that cause the blackouts include [3]:

- Planned maintenance work is not adequate.
- The forecasts about the changes of sudden atmospheric conditions are not adequate.
- Absence of control mechanisms (such as the static and dynamic reactive power controls) in HVDC for stabilizing power grids.
- Inadequate response from State Electricity Boards to control voltage and frequency.
- Transmission congestion that leads to the malfunction of distance relays.

As presented above, the Indian blackout was mainly caused by the insufficient management of the power quality, outage system, and peak load. In the past, the Indian grid measured the system parameters by remote terminal unit (RTU). It is suggested to improve the real time monitoring from RTU to phasor measurement unit (PMU), aiming to monitor the power system measurements at a rapid speed. The measurement by RTU is slow, and only provides RMS values without phase angles; furthermore, there is no time correlation for RTU measurements. The PMU measurements can improve the above mentioned technologies. Integration of distributed energy resources may be another way to prevent blackout incidents. Small distributed generations could prevent the chain reactions for power loss.

One of the most severe fault failures in Vietnam happens on May 22nd 2013. A fault on a 500 kV line tripped and separated the Southern grid from the North and Central grid of Vietnam system. The blackout fault happened when a