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Effects of electric power blackouts on steam turbine power plants

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ABSTRACT

In recent years the phenomenon of complete blackout happened many times in Sudan and causes several problems and defects in the power generation plants. There are many causes of power blackouts in Sudan, among them include: plants overloading due to too much power demand, failure in some power stations which makes the loads heavy on other stations and some human errors. This resulted in a power loss of over 10 GWH for 6 hours at a single blackout incidence in 2017. In this study, Khartoum north thermal power plant was taken as a case study since it is more affected by this phenomenon. In unit No. 6, which is steam power plant, both shafts of the high and low pressure turbines were seriously defected. Other defects were noticed in the crankshaft seats and oil rings in high and low pressure turbines. All those defects were mainly caused by high friction between rotating parts due to insufficient lubrication which happened when lubricant circulating and oil pumps were suddenly stopped by the complete blackout. Also some defects were observed in the electrical generator, mainly in the main shaft and its seats due to same reason mentioned above. To minimize the complete blackout phenomenon, some recommendations were suggested in this study. First, avoid the plant's overloading by installing more power plants to cater for the increase in demand. Second, increase

in monitoring of operations and maintenance programs, and finally reduce human errors by intensive training for all engineers and technicians.

1. Introduction

The introduction of electricity in Sudan began in 1908 by the installation of a 100kW Steam power plant (based on reciprocating engines connected to direct electrical current generators). The capacity of the plant was upgraded in 1925 to 3MW. Additional four steam turbines were installed in 1956 in Burri, with total capacity of 30MW. The first hydro-electric power plant was built in Sinner, 300km south of Khartoum in 1962 with capacity of 15MW. Two additional hydro-electric power plants were installed in El-Rosiers (280MW) and in Elgirba (12.6MW). There was change in policy in 1982 that resulted in the separation of Electricity Corporation from Water Corporation with each Corporation producing independent power and delivering services separately. The total installed hydro-electric power capacity connected to the national grid reached 335.6MW while the thermal power capacity was up to 656.72MW. There were other isolated thermal power station in several areas that were not connect to the national grid with installed capacity of 93.35MW. Additionally, in 2009, the Sudanese government created Merowe dam with a production capacity 1,250 MW in northern Sudan [1, 2].

2. Methodology

In this study,

a. An analytical descriptive approach was used.

b. A field survey and survey of the power plants linked to the national grid has also been made.

c. Data was also collected on the stations and faults that occurred due to this problem.

d. The faults were also analyzed and related to the problem.

Blackout Causes around the Globe

From 2011 to 2019, there were reports of numerous power systems blackouts in the world, that left millions of consumers stranded without power for hours. For instance, in Arizona, Southern California (USA) as well as some parts of northwestern Mexico reported tripping of major transmission line during peak load that resulted in the system failures. tripping of a major transmission line during peak load led to the system collapse occurred in the Southern California and Arizona, as well as parts of northwestern Mexico. On 8 September 2011, with 100% power restoration occurring from 6 to 12 hours depending on location, thereby affecting over five million residents [3–5]. On February 4th, 2011 power system blackout occurred in at least eight states in northeastern Brazil as the result of flaws in the transmission lines that lasted for about 16 h, thereby affecting around 53 million people [6,7].

An Indian blackout occurred on July 30th, 2012 which left half of the Indian country without electricity supply. The cause of the blackout was traced to the overloading of one of the 400 kV transmission lines in Gwali–Binar when the other transmission line was under maintenance [8, 9]. The imbalance of

demand-generation caused the successive system failure just a day after the initial incidence thereby affecting over 700 million people due to the interruption of about 32 GW of power [10]. This blackout was the largest reported power outage in recent history. In Vietnam, blackout occurred on May 22, the 2013. It was caused by careless movement of a truck deployed for planting trees in New Binh Duong City urban which caused massive power outage in the southern region of Vietnam. The power losses is estimated around 9,400 MW, and restoration occurred from 6 to 8 hours [11].

On 1 November 2014, Bangladesh suffered a nationwide power outage for almost 10 hours. The power outage in BPS affected about 150 million people [12-14]. On March 2015, the tripping of a heavily loaded 400 kV transmission line in Turkey caused a serious incident that led to a blackout, and left more than 90% of Turkey consumer without power [15].

On 7 June 2016, Kenya went without power for more than 4 hours. This nationwide blackout occurred when a monkey fell on a transformer in Gitaru hydro power station leading tripping of the transformer and interrupting 180 MW of power [16-17]. A complete power blackout hit all Sudan's states on February of 2017 due to a technical fault in the automatic protection system. This was the third time that a complete power outage has hit all Sudan's states during this year [18].

Table 1 showed the records of 66 major power systems blackouts in some parts of the world from 2011 to 2019. The survey does not include all the power systems blackouts in the world but provides an indicative statistic for acknowledging the causes of power system blackouts. Abnormal weather conditions such as heavy storms and severe winds as well as trees falling on transmissions lines contributed to the highest number of blackouts. Though, bad weather conditions cannot be forecasted with absolute certainty, better weather forecasting as well as improved power system monitoring and control can be significant in safeguarding power systems against such events.

Table 1: Blackouts in some parts of the world from 2011 to 2019.

Blackout Cause	Number Recorded	% of the Recorded Number
Weather/Trees	33	50
Faulty equipment or human error	21	31.8
Vehicle/Accidents	7	10.6
Over demand	4	7.6
Total	65	100

Power blackouts in Sudan

Blackout phenomenon is one of the phenomena that occur frequently in Sudan, especially in recent years, which made us do a study of this phenomenon to know its causes and the damages that resulted upon it in power plants. Table 2 shows the date this phenomenon occurred in Sudan for the period of 2011 – 2019.

As noted in Table 2, the recurrence of the blackout phenomenon in recent years, which repeatedly indicates that, is a real problem, so it is necessary to

know the causes of this phenomenon because it results in many damages and loss of power.

Table 2: The blackout phenomenon in Sudan for the period of 2011 – 2019.

DATE	TIME	Generation before blackout (MW)	Restoration time (H)	Losses (MWH)
23-Aug-11	17:22	1405	4:30	6176
18-Dec-13	11:35	877	3:20	2904.16
21-Dec-13	3:44	580	2:50	1359.45
4-May-15	20:39	1820	4:12	6300
4-Apr-16	2:00	1208	1:00	382
4-May-16	20:39	1820	3:53	7392
13-Oct-16	8:59	1979	6:06	8280
27-Feb-17	12:30	1553	6:00	10101
10-Jan-18	12:10	1528	3:13	4508
3-Jan-19	13:29	2220	2:49	4800

Causes of power blackouts in Sudan

There are many causes of power blackouts in Sudan of them as a whole: too much demand, some power stations are out of service which makes the loads heavy on other stations and some human errors. Below is breakdown of the reasons for this phenomenon in Sudan between 2011 and 2019 [19].

- In 2011 the cause of the power blackout was close of TR07 at Merowe Plant and trip of all Merowe Plant transformers by boucle trip/ Total Collapse occur after restoration.
- In 18 December 2013 the cause of power blackout was loss of all units in Merowe Plant power station caused by the loss of DC system in the plant. Merowe Plant was carrying 68.2% of the system load.
- In 2015 the cause of power blackout was circuit breakers in Merowe Plant opened also distance direct transfer trip signal was sent to Markhyat side, Merowe Plant completely isolated (Merowe Plant was carrying more than 52% of the system total load.
- In 4 April 2016 the cause of power blackout was Partial Blackout due to Merowe Plant transformer 04 Tripped (Differential Protection) and two lines MWP-MRK, also tripped from both sides.
- In 4 may 2016 the cause of power blackout was All MWP Units Tripped (circuit breakers tripped due to Breaker Failure Protection) also Line 77.
- In 13 October 2016 the cause of power blackout was Real earth fault at 110Kv due to closure of transformer 02 Isolator - jumper not disconnected "connecting to Earth" maloperation.

- In 2017 the cause of power blackout was all 500KV (MRK 2 lines + ATB line) were tripped from both sides "maloperation".
- In 2018 the cause of power blackout was Kosti power plant tripped out three units - consequentially the tie line tripped 200MW.
- In 2019 the cause of power blackout was tripping of 2 lines Mashkour-Rabak power plants and 2 lines Sinnar junction-Maringan power plants.

Damages caused by power blackout at Khartoum North Thermal Station

In January of 2019, the phenomenon of power blackout occurred. It caused very severe damages to mechanical parts of the station, and it caused great damage to the bearing and the turbine shaft in Unit No. 6. Table 3 shows the detailed of some of the mechanical parts damaged in this unit.

Table 3: The mechanical parts damaged by blackout phenomenon in Bahri Thermal Station

Mechanical parts damaged	**Damage details**	**Action to be taken**	**figures**
HP TURBINE ROTOR	Scoring line marks observed on HP Turbine rotor front journal area.		
HP Turbine front journal bearing	Front journal bearing found in damaged condition	Bearing to be sent to STS work shop in India	
HP Turbine front oil seal	Front oil gland (Bearing side) fins got damaged due to Rubbing	Fins replaced (Bearing side) with new one, oil seals to be send STS work shop.	
LP Turbine front journal	Heavy deep scoring line marks were observed on LP front journal area.	Polishing of the LP front journal to remove the existing scoring. This will in turn reduce the size of the Journal.	

LP Turbine rear oil gland	Oil gland fins got damaged due rubbing	- Oil gland (Segments) to be replaced with new one. - Oil gland to be sent to STS work shop in India.	
Generator rotor front journal	Minor Scoring line marks observed on journal area	Polishing of the LP front journal to remove the existing scoring. This will in turn reduce the size of the Journal.	
Generator rear journal	Minor Scoring line marks observed on Rear journal area	Polishing of the LP front journal to remove the existing scoring. This will in turn reduce the size of the Journal.	
Generator air seal	- Generator front and rear air seal got damaged due to rubbing. - Exciter Air seal fins got damaged due rubbing.	- Replacement air seals with new one. Old air seals to be sent to STS Work shop in India for reveres engineering Description	

3. Conclusion and Recommendations

The causes of blackout phenomenon in Sudan can be summarized in the following points:

- Plant overloading.
- Electrical faults.
- Operating errors.
- Some stations are out of service.

The phenomenon of power blackouts has several effects. In this study, the effect on the steam generating station was studied. In January 2019, after this phenomenon occurred that led to the loss of 4.8 GWH of electricity, Unit No. 6

was visited at Bahri Thermal Station. The effects of this phenomenon on Unit No. 6 have also been studied; it can be summarized in the following points: large damage to the turbine rotor, journals, bearings, oil seals and oil gland, in addition to the generator's journals and air seals. These damages increased the maintenance cost and decrease the power generation capacity of the plant.

To avoid overloading of the power stations due to excessive power demand, more power plants should be installed so that the production capacity should be greater than the total demand. Also, the operations and maintenance programs should be adequately monitored.in addition to, intensive training should be provided to all engineers and technicians to reduce operation errors.

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