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A Comprehensive Review of Critical Failures and Blackouts in Power Systems

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***Abstract**:* Electric power is the backbone of modern society, and any large-scale outage can cause severe disruption to social, economic, and industrial life. A blackout represents the most critical type of power outage, typically resulting from cascading failures across interconnected grids. This paper reviews the phenomenon of power system blackouts, with a particular focus on the Indian blackout of July 2012. Causes, consequences, preventive measures, and global experiences are discussed, with lessons for improving grid reliability and resilience.

Keywords: Power system blackout, Critical failures, Collapse of power grid.

INTRODUCTION*:*

Critical Failures - Blackouts

The power systems worked by the utilities in creating nations experience the ill effects of enormous hole between the interest and age, insufficient transmission limit and non-uniform area of load focuses and producing stations, power segment changes in deregulation situation made the power framework helpless against blackouts because of events of critical disappointments in power systems. Significant power system breakdowns have been happening generally in the between associated electrical lattices. Certain specialized elements assumed a significant job in the as of late happened critical disappointments.

1. Inaccurate operation of defensive system.
2. Voltage instability.
3. Frequency instability.
4. Critical overloads.
5. Absence of control plans to control quick frequency decrease following the aggravation.
6. Absence of supplementation of reactive assets to address the voltage breakdown.
7. Absence of interest side and the executive's techniques with robotization to forestall course disappointments

Consequently, the critical disappointments in the power system have exhibited difficulties to the power system organizers and operators. This has made the investigation of critical disappointments as a prompt need drawing the consideration from the power system specialists and academicians.

Occurrences of Blackout

A portion of the critical disappointment occasions happened far and wide are details beneath,

WSCC 14th December, 1994

On 14th December, 1994 at 1:25AM the abnormal overload happened from south to North West. A solitary stage to ground fault on 345kV line caused the incidental stumbling of the extra 345kV lines encouraging a similar substation. The over load in the rest of the lines caused the under voltage condition because of the debilitated network, the lines stumbled in a steady progression in domino impact style.

WSCC 2nd July, 1996

At 1:25PM on 2nd July, 1996 a huge unsettling influence happened in WSCC system. A short out happened on 345kV line and was stumbled effectively. This aggravation made the parallel lines is stumbled. A SPS conspire was started in the wake of stumbling of the two lines which caused the shutdown of producing units at the Jim Bridger Plant. The under voltage and entomb motions grew rapidly all through the system and brought about loss of 2500MW of power.

WSCC 3rd July, 1996

At 2:03PM on 3rd July, 1996 a succession of starting occasions that was like the earlier day occasions happened in WSCC system. After the shutdown of two producing units at Jim Bridger Plant, the under-voltage issue started to create The system operator depended on shut the load request of 1200MW because of his earlier day experience. Because of this definitive activity the system was spared and just set number of clients was influenced.

WSCC 10th August, 1996

At 15:48hrs on 10th August, 1996, because of the predominant of high temperatures all through the west coast, which lead to high electricity request. Various transmission lines blackout in Washington over a time of 1hr debilitated the transmission system which leads to the developing motions in the system. Three 500kV pacific AC tie lines and ± 500kV pacific DC tie lines were lost because of the motions which caused the course blackouts without control.

Brazil 11th March, 1999

At 22:16hrs on 11th March, 1999 a stage to ground fault happened on 440kV bus bar and caused the opening of the considerable number of lines associated with the substation, where in there was no bus bar assurance. The Brazil power system could withstand the different copying possibility for just 10secs. The power system started to crumple at the moment of disengagement of the tie lines between two areas, the blackout of significant power plants, loss of HVDC joins and 765kV AC joins, at long last lead to system detachment coming about into the loss of 24,731MW load, influencing 75 million individuals.

US Midwest and North-East Canada 14th August, 2003

Succession of line trippings in the North-East Ohio caused substantial loadings on number of transmission lines, the course blackout happened as more than 508 creating units at 265 power plants were lost. The northern piece of the entire eastern interconnection was broken separated into five islands. The blackout influenced around 50 million individuals and caused the loss of 61,800 megawatts of electric load in the conditions of Ohio, Michigan, Pennsylvania, New York, Vermont, Massachusetts, Connecticut, New Jersey and the Canadian territory of Ontario

Italy, 28th September, 2003

In the evening of 28th September, 2003 at 03:01:42, the 380kV transmission line interfacing Italy and Switzerland had a flashover because of falling of trees and the line got stumbled. This stumbling caused some other transmission lines to get overloaded. Around 25 minutes after the fact, two transmission lines, the 380kv interfacing Italy and Switzerland and furthermore the 220kV lines of Italy and Switzerland, were stumbled because of overload. At 03:25:26, an extraordinary insurance plot consequently detached the 380kV line of Austria and Italy to secure the Austria system. Following the last possibility, the Italian network lost its synchronism and got isolated. An aggregate of 27.7GW load was lost and 57 million individuals were influenced.

India 30th and 31st July 2012

There was a significant lattice unsettling influence in Northern Region at 02.33 hrs on 30-07-2012. Northern Regional Grid load was around 36,000 MW at the hour of aggravation. Therefore, there was another matrix aggravation at 13.00 hrs on 31-07-2012 bringing about breakdown of Northern, Eastern and North-Eastern local networks. The all out load of around 48,000 MW was influenced in this blackout. On both the days, not many pockets made due from blackout.

Brief Sequence of Events which led to the Grid Collapse on 30th and 31st July 2012,

(i) On 30th July, 2012, after NR (Northern Region) got isolated from WR (Western Region) because of stumbling of 400 kV Bina-Gwalior line, the NR loads were met through WR-ER (Eastern Region)- NR course, which caused power swing in the system. Since the focal point of swing was in the NR-ER interface, the comparing tie lines stumbled, separating the NR system from the remainder of the NEW framework system. The NR framework system fell due to under frequency and further power swing inside the area.

(ii) On 31st July, 2012, after NR got isolated from the WR because of stumbling of 400 kV Bina-Gwalior line, the NR loads were met through WR-ER-NR course, which caused power swing in the system. On this day the focal point of swing was in the ER, close to ER-WR interface, and, subsequently, in the wake of stumbling of lines in the ER itself, a small piece of ER (Ranchi and Rourkela), alongside WR, got secluded from the remainder of the NEW framework. This caused power swing in the NR-ER interface and brought about further partition of the NR from the ER-NER system. Therefore, all the three matrices crumbled because of various stumbling ascribed to the inward power swings, under frequency and overvoltage at better places.

(iii) The WR system, be that as it may, made due because of stumbling of scarcely any generators in this locale on high frequency on both the days.

(iv) The Southern Region (SR), which was getting power from ER and WR, additionally made due on 31st July, 2012 with part loads remained nourished from the WR and the operation of barely any protection system, for example, AUFLS and HVDC power inclining.

Modeling Blackouts,

Consider, checking mixes of disappointments in a power system model with n segments. For useful models, for huge blackouts, n is in the thousands or several thousand Checking for single disappointments requires just n cases to be checked, yet checking for blends of k progressive disappointments requires n k cases to be checked, which quickly becomes infeasible even with the fastest computers for unassuming estimations of k. Be that as it may, huge blackouts can include falls of tens to many occasions. Plainly thoroughly checking every single imaginable mix of cascading disappointments that could prompt blackouts in commonsense power system models is computationally infeasible.

Cascading marvels are confused as a result of the decent variety of disappointments and the wide range of instruments by which disappointments can associate. There are shifting modeling prerequisites and timescales (milliseconds for electromechanical impacts and many minutes for voltage backing and warm warming). Mixes of a few of sorts of disappointments and cooperation's can normally happen in enormous blackouts, including cascading overloads, disappointments of insurance gear, transient instability, constrained or unforced starting blackouts, reactive power issues and voltage breakdown, programming, communication, and operational blunders, crisscross between planning thinks about and operational condition, uncommon and irregular disappointments or mixes of disappointments, working missteps and absence of situational mindfulness.

For examination of a portion of the general highlights of collaborations between the infrastructure system by utilizing straightforward models are discovered required, D. E. Newman, et al proposed two such models. One is probabilistic model, course and the other model is dynamic complex system model (DCSM), which can work in self-sorted out critical state. In both the models the limit above which the events of cascading disappointments is portrayed by the expanding parameter λ. The permeation point is at λ=1, where the likelihood thickness of disappointments for course is a power law with example - 1.5 while for DCSM it is to some degree closer to - 1.0 . For the DCSM model it is discovered that enormous disappointments are bound to be synchronized over the two dynamical systems, which is probably going to be the power law found in the likelihood of disappointment with size is less steep with the coupling. This implies in coupled systems there is a more prominent likelihood of huge disappointments. With DCSM model the other significant part of infrastructure that can be investigated is non-uniform and non-symmetric couplings.

Since a thorough calculation of every single imaginable blend of disappointments is infeasible, and making a point by point model of every single imaginable disappointment and their communications is past the cutting edge, bargains are required in modeling and investigating cascading disappointment, for example,,

- Dissect the point by point disappointments and communications in a solitary blackout after it happens.
- Analyze a determination of generally plausible or high hazard disappointments.
- Statistically, model the general movement of cascading disappointments, while ignoring subtleties of the connections.
- Analyze a disentangled power system model to clarify the mass properties of cascading disappointments, as opposed to modeling the entirety of the gear in detail.
- Analyze one or just a couple of the cascading instruments.
- Analyze just an underlying piece of the arrangement of disappointments; for instance, to a limited extent of "no arrival."
- Use continuous data about the current power system design and the advancement of the course (if moderate enough) as far as possible the conceivable outcomes to be considered.

Mechanism of Blackouts,

Definition of Cascading,

Cascading disappointment is characterized as a grouping of ward disappointments of individual segments that progressively debilitates the power system. Cascading disappointment is the primary system of enormous blackouts. Disappointments progressively debilitate the system and make further disappointments more probable with the goal that a blackout can engender to cripple huge parts of the electric power transmission infrastructure whereupon current society depends. There are a wide range of sorts of connections by which disappointments can spread over the span of a blackout. For instance, a transmission line stumbling can cause a transient, the overloading of different lines, the operation or disoperation of transfers, reactive power issues, or can add to system hazards or operator stress. In any case, for every one of these kinds of collaboration, the danger of cascading disappointment for the most part turns out to be progressively extreme as by and large system loading increments. Be that as it may, precisely how does cascading disappointment gotten almost certain as loading increments? There is a critical loading at which the likelihood of enormous blackouts and the mean blackout size begin to rise rapidly and at which the likelihood conveyance of blackout sizes has power law reliance. The importance of the power law in the likelihood circulation of blackout size is that it infers a considerable danger of huge blackouts close to the critical loading. It is imperative to check and analyze criticality in an assortment of power system blackout models to discover the degree to which it is a marvel all around related with cascading disappointment of power systems. Models of cascading disappointment in power systems are portrayed in the accompanying segments.

At the point when new arrangements are to be built up that target staying away from the enormous scale blackouts to happen, it is critical to get causes and included instruments in the process prompting a blackout. Fig. 1 shows a general arrangement of occasions that can prompt a blackout.

The fundamental driver of blackout is a recurrent progression of disappointments, that disengages the transmission lines or generators and disappointment of the endurance of the shaped island assuming any. A down to earth issue may begin as a significant fault that causes enormous varieties in power stream and voltages which thusly can cause the harm of age units or transmission lines which further prompts age load irregularity.

Industry Practice

Transmission Operations is to guarantee that the transmission system is worked so instability, uncontrolled detachment, or cascading blackouts won't happen because of the most serious single Contingency and indicated various Contingencies." and requires that: "Every Transmission Operator will work so instability, uncontrolled partition, or cascading blackouts won't happen because of the most extreme single possibility." and that: "Every Transmission Operator will, when pragmatic, work to ensure against instability, uncontrolled division, or cascading blackouts coming about because of numerous blackouts, as determined by Regional Reliability Organization arrangement."

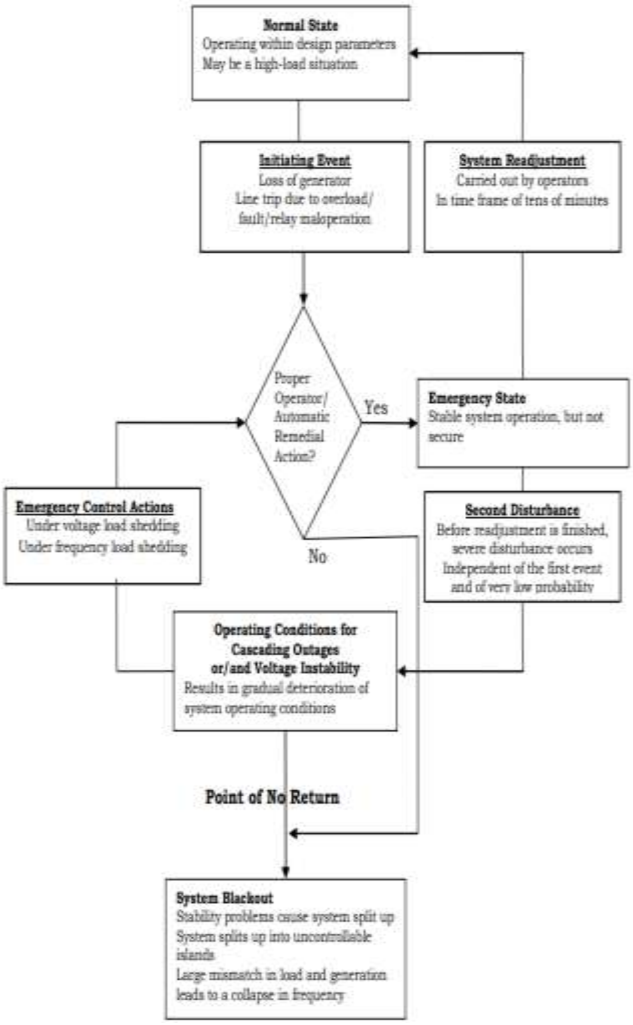

Figure 1: Mechanism in the evolution of a Power System blackout

Emergency Preparedness and Operations requires that: "In the wake of making all other therapeutic strides, a Transmission Operator working with inadequate age or transmission limit will shed client load as opposed to hazard an uncontrolled disappointment of parts or cascading blackouts of the Interconnection." The reason for is to guarantee that "a Transmission Operator working with lacking age or transmission limit" has "the ability and power to shed load instead of hazard an uncontrolled disappointment of the Interconnection."

Various classes are characterized in transmission planning to address the system working condition under various classifications.

Class A (normal system operations without any possibilities), Category B (occasion bringing about the departure of a solitary component or N-1), Category C (event(s) bringing about the loss of at least two (different) components or N-2), and Category D extraordinary occasion bringing about at least two (numerous) components evacuated

Class A examination is clear: on the off chance that any component surpasses its pertinent rating, at that point transmission organizers will include new transmission offices, or compose and execute strategies to stay away from the condition. In the working time allotment, the transmission system will be reconfigured or re-dispatched to take out any infringement. Classification B examination pursues a way like Category A, then again, actually loss of every office must be considered. Tenable single possibilities are generally chosen utilizing building judgment, however current figuring ability permits examination of all disappointments of single components or if nothing else a wide choice of them.

Classification C examination is convoluted by the quantity of occasions that must be considered. Ordinarily, this rundown is decreased to a sensible number of occasions utilizing designing judgment. Possibilities that don't cause material rating infringement are rejected. The working measures center just on most serious single possibility.

The Category D standard used to incorporate a disallowance against cascading,

Properties of Cascading

How much rarer are enormous blackouts than small blackouts? One may expect a likelihood circulation of blackout size to tumble off exponentially as the size of the blackout increments. That is, multiplying the blackout size squares its likelihood thus, after numerous squarings, the biggest blackouts have vanishingly small likelihood. In any case, investigations of North India blackout measurements show that the likelihood dissemination of blackout size doesn't diminish exponentially, yet rather has an estimated power law locale with an example, between – 1 and – 2.

The power law data from various nations proposes that huge blackouts are significantly more likely than may be normal from the basic likelihood conveyances that have exponential tails. The power law area is constantly restricted in degree by a limited slice off relating to the biggest conceivable blackout.

Some Models of Blackouts

1. Cascade Model

The Cascade model is a systematically tractable probabilistic model of cascading disappointment that catches the debilitating of the system as the course continues. There are an enormous yet limited number n of indistinguishable parts and every segment has a degree of loading or stress. The underlying load on every segment is a s-autonomous uniform arbitrary variable over a fixed scope of loading. There is an underlying aggravation to the system that adds extra loading to every segment. Every segment has a most extreme loading edge and falls flat if this edge is surpassed. At the point when any segment falls flat, the various parts are moreover loaded with the goal that underlying disappointments can prompt a cascading grouping of disappointments as segments progressively overload and furthermore load different segments. The course proceeds until there are no further disappointments or every one of the parts are fizzled. The all out number of bombed segments in the Cascade model pursues a soaking variation of the quasibinomial dispersion. The fundamental parameters are the size d of the underlying unsettling influence and the sum p by which load of different segments is augmented when a segment comes up short, which controls the degree to which the course engenders.

Normalized cascade Algorithm

1. All n parts are at first unfailed and have introductory loads that are n sindependent irregular factors consistently conveyed in {0; 1}
2. Add the underlying unsettling influence d to the load of every segment. Instate the age number I to zero.
3. Test each unfailed part for disappointment: For j = 1,… .,n, on the off chance that segment j is unfailed and its load > 1, at that point segment j comes up short. Assume if mi segments bomb in this progression.
4. On the off chance that mi = 0, stop, the cascading procedure closes.
5. On the off chance that mi > 0, at that point increase the part loads as indicated by the quantity of disappointments mi; Add mip to the load of every segment for j=1… N.
6. Presently, increase age number I and go to step 2.
7.

Branching Process Model

The branching procedure model of cascading disappointment is a standard Galton Watson branching procedure with Poisson posterity appropriations, then again, actually there are a limited number n of segments. The disappointments are delivered in ages. In age zero, there is an underlying Poisson dispersion of disappointments with implies that speaks to the underlying aggravation to the system. Every disappointment in every age delivers further disappointments as indicated by a Poisson posterity circulation with mean λ until no more disappointments are created or every one of the parts fall flat. The complete number of disappointments pursues an immersing variation of the summed-up Poisson dissemination. The principle parameters are the mean size of the underlying unsettling influence and the mean number of posterity disappointments λ which controls the degree to which the course engenders.

Computational Study of Blackout Model

There are a limited number of parts that can flop in a blackout, so it must be perceived that the cascading procedure will soak when the vast majority of the segments have fizzled. Additionally, many watched cascading blackouts don't continue to the whole interconnection passing out. The explanations behind this may well incorporate hindrance impacts, for example, load shedding mitigating system stress, or effective islanding, that apply notwithstanding the stochastic variety that will constrain some cascading groupings. Comprehension and modeling these restraint or immersion impacts is significant. Be that as it may, in evaluating λ, we keep away from this issue by dissecting the cascading procedure before immersion happens. Diagnostic recipes for the all out number of parts fizzled can be acquired at times. For instance, accept that there are M0 beginning disappointments, the posterity dissemination is Poisson with mean λ, and the procedure immerses when n parts fall flat. At that point the absolute number of disappointments S is appropriated by a soaking Borel-Tanner conveyance.

POWER SYSTEM SECURITY AND ITS THREATS

Power method protection might be looked upon as the likelihood of the system's operating point staying within appropriate ranges, provided the probabilities of changes of the system (contingencies) as well as the surroundings of its.

Power method protection is actually among the difficult things for the power system engineers. This particular protection assessment is important as it provides the expertise of the device state in the event of contingency. Contingency analysis method has been commonly utilized in order to anticipate the outcome of outages as failure of power system components for example generator, transformer, transmission line etc, also to take action that is required to keep the energy system secure & reliable. Take of offline analysis to foresee the impact of unique contingency is a tedious job as being a power structure includes huge selection of elements. Practically, just selected contingencies are going to lead to serious ailments in power process. The procedure for determining serious contingencies is actually referred as contingency choice and this could be accomplished by calculating performance indices for every kind of contingency. In this particular paper contingencies such as for instance individual transmission line as well as double transmission line outages are actually considered.

Overall Security Problem

In light of the Security level of power system, its working states are ordered into Normal State, Alert State, Emergency State, In Extremis state as appeared in the Fig.1.4.

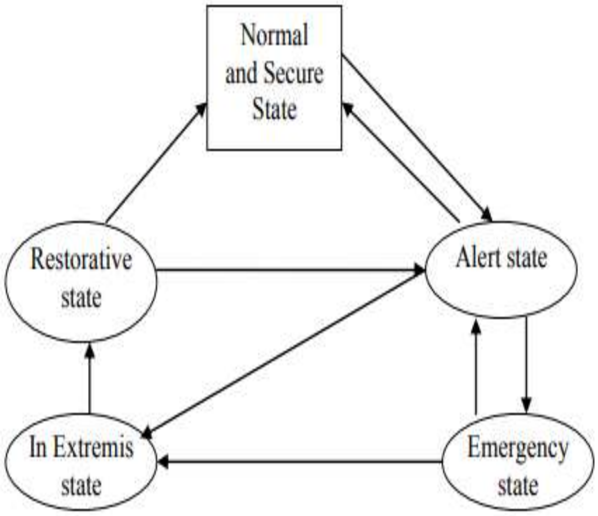

figure 2: The probable operating states of power system in security analysis

- **Normal State:** In normal express, the power balance among age and burden is fulfilled and no hardware is over-burden. Every one of the voltages is inside limits. Also, the system has adequate security edge to withstand any of the solid possibilities.
- **Alert state:** Under this express, the power balance among age and load is still met. No gear is over-burden. No voltage is out of its cutoff points. Be that as it may, when an extreme possibility happens, the system will either have over-burden types of gear or have voltage infringement.
- **Emergency state:** The power balance among age and load is as yet fulfilled. Be that as it may, either over-burden or voltage infringement occurs in emergency state. In the event that appropriate restorative control moves are made, the state can in any case be reestablished to normal state or if nothing else alert state.
- **In Extremis State:** Under this express, the power balance among age and burden is lost. Voltage infringement may occur and some gear is over-burden. There are cascading blackouts. Burden shedding might be taken, to spare however much of the system as could reasonably be expected.
- **Restorative State:** Under this express, the administrator performs control activities to reestablish all system loads. Contingent upon various cases, the system can arrive at either normal or alert state.

TABLE I: Regional Grids and Their Acronyms.

Grid Name	Acronym
Northern Regional Grid	NR
Western Regional Grid	WR
Eastern Regional Grid	ER
North-Eastern Regional Grid	NER
Southern Regional Grid	SR

S.no.	Time	Transmission element	Reason
1	29th July 2012 15:15	220 kV Kota – Badod	Tripped due to operation of distance protection three phase Zone-1 indications at Badod end
2	29th July 2012 15:40	220 kV Bhinmal(PG) – Sirohi	Phase to earth fault.
3	29th July 2012 21:45	400 kV Bhinmal – Kankroli	Tripped due to insulator de-capping.
4	29th July 2012 22:18	400 kV Zerda – Kankroli	Emergency outage for a period of two hours to takeout one Tool &Plant which got stuck with one polymer insulator.

TABLE II: Sequence of Outages on 29 July.

Date & Time	Transmission Element
30th July, 2012 02:33:11	400kV Bina – Gwalior-1 Line Tripped.
30th July, 2012 02:33:13	220 kV Gwalior-Malanpur 1. Zone-1 Tripped (on Power Swing) with the above events, practically all the AC links from the WR to the NR were lost.
30th July, 2012 02:33:14	400 kV Jamshedpur – Rourkela line, line-1, 2, and 3 tripped on zone 3 protection.
30th July, 2012 02:33:14	400 kV Gorakhpur-Muzaffarpur-2 tripped (on Power Swing).
30th July, 2012 02:33:15	400kVBalia – Biharsharif-2 line tripped (on power swing).

TABLE III: Sequence of Outages on 30 July.

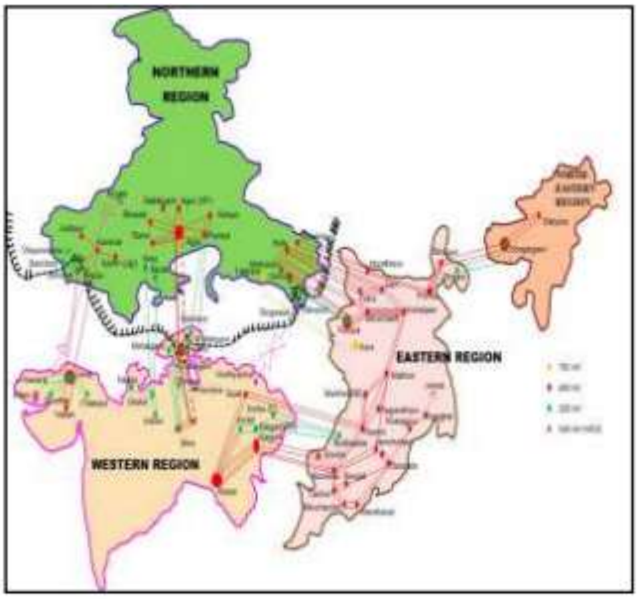

Fig. 3 Regional Grids on Map of INDIA

Time	Transmission Element
31 July,2012 13:01:28	400 kV Kankroli-Jodhpur tripped due to dip in voltage, Wagoora-Kishenpur (1&2) (tripped due to Power Swing)
31 July,2012 13:01:30	Ballabhgarh-Gr Noida tripped, Z1, 3phase, Kanpur-Panki-1 tripped (Under voltage)
31 July,2012 13:03:18	400kV Patna-Balia-2 tripped (3-ph fault), Kankroli - Debari 220kV tripped (Under voltage protection)

TABLE III: Initiation of Outages on 31 July

Date &Time	Transmission Element
31 July,2012 13:00:13	400kVBina – Gwalior-1,2 line tripped 220kV Shivpuri-Sabalgarh-1 tripped.
31 July,2012 13:00:15	132kV Pichhore-Shivpuri tripped 400 kV Ranchi- Maithon-1 tripped (due to Power Swing).
31 July,2012 13:00:18	220 kV bus coupler tripped at Tarkera tripped 400 kV Jamshedpur-Rourkela-1 tripped.

TABLE IV: Sequence of Outages on 31 July

CONCULUSION

Large-scale power system blackouts represent one of the most severe challenges to the reliability and security of modern electric power networks. This paper has reviewed the phenomenon of power system blackouts with emphasis on their causes, mechanisms, historical occurrences, and modeling approaches, with special reference to the Indian grid disturbances of July 2012. The analysis highlights that blackouts are rarely the result of a single failure; rather, they emerge from cascading sequences of technical, operational, and sometimes organizational failures within highly interconnected power systems.

Key contributing factors such as protection system mal-operation, voltage and frequency instability, critical overloading, insufficient reactive power support, and lack of effective control and automation schemes have been identified as dominant triggers of cascading failures. The review of major international blackout events demonstrates that despite regional and structural differences, the underlying mechanisms of cascading outages exhibit similar characteristics worldwide, often governed by critical system loading and complex interdependencies.

The discussion on blackout modeling shows that exhaustive enumeration of all possible cascading scenarios is computationally infeasible for large-scale systems. Therefore, probabilistic, simplified, and statistical models play a vital role in understanding blackout dynamics, assessing risk, and identifying critical operating thresholds. Power-law behavior observed in blackout size distributions further indicates the inherent vulnerability of power systems near critical operating points.

Overall, this study emphasizes the need for strengthened grid planning, enhanced situational awareness, improved protection coordination, real-time monitoring, and proactive emergency control strategies such as load shedding and islanding. Continuous learning from past blackout events, coupled with advanced modeling and smart grid technologies, is essential to enhance power system resilience and to minimize the social and economic impacts of future large-scale blackouts.

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REFERENCES

1. (Berenji et al., 2003) H. Berenji, J. Ametha, and D. Vengerov. Inductive Learning for Fault Diagnosis.In Proceedings of the 12th IEEE International Conference on Fuzzy Systems, pages 726–731, 2003.

2. (Clarkson, 2004) Simons C. Eckert C. Clarkson, P.Predicting change propagation in complex design. Journal of Mechanical Design, 126:788, 2004.

3. (de Kleer and Kurien, 2003) J. de Kleer and J. Kurien.Fundamentals of model-based diagnosis. Safe Process, 2003.

4. (Grantham-Lough et al., 2008) K. Grantham-Lough,R. B. Stone, and I. Y. Tumer. ImplementationProcedures for the Risk in Early Design (RED)Method. Journal of Industrial and Systems Engineering,2(2):126–143, 2008.

5. (Huang and Jin, 2008) Z. Huang and Y. Jin. ConceptualStress and Conceptual Strength for FunctionalDesign-for-Reliability. In Proceedings of the ASMEDesign Engineering Technical Conferences; InternationalDesign Theory and Methodology Conference,2008.

6. (Meshkat et al., 2007) L. Meshkat, S. Jenkins,S. Mandutianu, and V. Heron. Automated Generationof Risk and Failure Models during Early PhaseDesign. In Proceedings of the IEEE AerospaceConference, 2007.

7. Manish Parihar and M.K. Bhaskar, International Journal of Research and Innovation in Applied Science (IJRIAS) | Volume III, Issue VI, June 2018|ISSN 2454-6194 page: -8-11

8. Hassan Haes Alhelou (2019). A Survey on Power System Blackout and Cascading Events: Research Motivations and Challenges. Department of Electrical and Computer Engineering, Isfahan University of Technology. Published: 20 February 2019.

9. Amini, S.; Pasqualetti, F.; Mohsenian-Rad, H. Dynamic load altering attacks against power system stability: Attack models and protection schemes. IEEE Trans. Smart Grid 2018, 9, 2862–2872. [CrossRef]

10. Eaton, B.T.United States Annual Report 2013; Technical Report, 2013. Available online: http://powerquality. eaton.com (accessed on 10 February 2018).

11. Sudeep Dattatraya Kulkarniirlekar , " Blackouts in the power system", IJEER ISSN 2348-6988 (online) Vol. 3 Issue 4, pp: (1-7), Month: October - December 2015.

12. Md. MoyeedAbrar, "Power cut off and Power Blackout in India a Major threat- An Overview", International Journal of Advancements in Research & Technology, Volume 5, Issue 7, July-2016, ISSN 2278-7763.

13. S. Shivashimpiger, Siridevi, V. Parthasarathy, Dr. H.M.

14. Ravikumar, "A Qualitative analysis of Power System Blackouts - Northern Grid Case Study", (IJETER), Vol. 3 No.6, Pages : 373 - 379 (2015) Special Issue of NCTET 2K15 - Held on June 13, 2015 in SV College of Engineering, Tirupati.

15. Report on the Grid Disturbances on 30th July and 31st July 2012, Submitted in Compliance to CERC Order in Petition No. 167/Suo- Motu/2012 dated 1st Aug2012.

16. Ken Koyama, "Blackout and Impact of World"s Largest Blackout In India", IEEJ special bulletin, August 2012.

17. Ministry of Power, Government of India, website http://powermin.nic.in/.

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