

## Article

# Recovering Power Grids Using Strategies Based on Network Metrics and Greedy Algorithms

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**Abstract:** For this study, we investigated efficient strategies for the recovery of individual links in power grids governed by the direct current (DC) power flow model, under random link failures. Our primary objective was to explore the efficacy of recovering failed links based solely on topological network metrics. In total, we considered 13 recovery strategies, which encompassed 2 strategies based on link centrality values (link betweenness and link flow betweenness), 8 strategies based on the products of node centrality values at link endpoints (degree, eigenvector, weighted eigenvector, closeness, electrical closeness, weighted electrical closeness, zeta vector, and weighted zeta vector), and 2 heuristic strategies (greedy recovery and two-step greedy recovery), in addition to the random recovery strategy. To evaluate the performance of these proposed strategies, we conducted simulations on three distinct power systems: the IEEE 30, IEEE 39, and IEEE 118 systems. Our findings revealed several key insights: Firstly, there were notable variations in the performance of the recovery strategies based on topological network metrics across different power systems. Secondly, all such strategies exhibited inferior performance when compared to the heuristic recovery strategies. Thirdly, the two-step greedy recovery strategy consistently outperformed the others, with the greedy recovery strategy ranking second. Based on our results, we conclude that relying solely on a single metric for the development of a recovery strategy is insufficient when restoring power grids following link failures. By comparison, recovery strategies employing greedy algorithms prove to be more effective choices.

**Keywords:** power grids; network resilience; network recoverability



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## 1. Introduction

The power grid system is vulnerable to disruptions caused by manufacturing defects, natural disasters, and human actions, such as terrorist attacks [1–3]. Even minor initial disturbances can lead to severe consequences, including economic and social instability [4–6]. To reduce the costs associated with the disruptions, one research direction is to enhance the robustness of the power grid to withstand perturbations. The other direction is to propose efficient restoration strategies.

The power grid can be represented as a complex network, where nodes represent generators and loads, and where links represent transmission lines and transformers. Analyzing the power grid's robustness from a network perspective has attracted significant attention. Network robustness is typically evaluated by assessing changes in network performance due to fluctuations such as node removals or link removals [7]. Identifying

# Recovering Power

**Tyndale**



## **Recovering Power:**

**Recovering Power** Anthony Seldon, 2005-04-01 The Conservative Party's periods in opposition have been of crucial importance. They have seen major changes in direction and often been the springboard for recovering power. There have also been leadership crises and bitter divisions and recovery was never inevitable. In the first study to examine the topic as a whole, leading authorities present new evidence and interpretations. The book makes a significant contribution to our understanding of the Conservative Party and of opposition in modern British politics. Recovering Naval Power John Hattendorf, Geoffrey Till, 2023-11-30 This book offers a new edition of Henry Maydman's work *Naval Speculations* with a detailed commentary by two leading experts on its importance to the naval issues of the 21st century. Written at a revolutionary and troubling time, Maydman's 1691 book offers an analysis of the state of the Royal Navy at the time together with a set of recommendations for its improvement. It not only tells us a good deal about the Royal Navy of the time but also provides a general theory of why navies decline and what can be done to rejuvenate them. *Recovering Naval Power* shows that the issues he identifies have applied to every navy in every period. We are now seeing the dramatic rejuvenation of the Chinese Navy and the reactions to it of the US and other navies together with a new rise in naval tensions in the Euro Atlantic. Despite the obvious political, economic and technological differences between Maydman's day and ours, this work shows that his recommendations could hardly be more relevant in today's circumstances. Alongside the modified text of *Naval Speculations*, this book includes a preface and two chapters addressing first the Royal Navy of Maydman's time and his role in it and second the relevance of what Maydman said for the navies of the 21st century. The book concludes with some overall comments about Maydman and the recovery of naval power and recommendations for further reading. This book will be of much interest to students of naval history, maritime power, strategic studies and International Relations in general. Power Recovery from Low Grade Heat by Means of Screw Expanders Ian K Smith, Nikola Stosic, Ahmed Kovacevic, 2014-05-06 Current concerns with climate change have resulted in greatly increased interest in power recovery from low grade heat sources. This includes both hot fluid streams which can be expanded directly to produce mechanical power and those which act as a source of heat to closed cycle power generation systems. *Power recovery from low grade heat by means of screw expanders* with a generalised overview of how best to recover power from such sources based on thermodynamic considerations which differs to the approach used in classical thermodynamics textbooks and which includes an introductory description of the types of working fluid that are used in systems used to recover power from such sources and the criteria that must be taken into account in their selection. This is followed by a description of the mathematical modelling of twin screw machine geometry. The modelling of the thermodynamics and fluid flow through such machines is then given together with how this is used to predict their performance. Finally a detailed description is given of systems currently used or projected both for direct expansion of the source fluid and by recovery of heat from it which includes those which are

particularly suited to the use of screw expanders in place of turbines A novel generalised approach to the thermodynamics of power recovery from low grade heat systems Gives criteria for working fluid selection Provides details of and how to model screw expander geometry Details how to estimate screw expander performance Surveys types of system used for power recovery from low grade heat and where this can be improved by the use of screw expanders

**SAP HANA on IBM Power Systems Backup and Recovery Solutions** Dino Quintero,Rosane Goldstein,Adriana Melges Quintanilha Weingart,Pia Nymann,Andrei Socoliuc,IBM Redbooks,2021-05-27 This IBM Redpaper Redbooks publication provides guidance about a backup and recovery solution for SAP High performance Analytic Appliance HANA running on IBM Power Systems This publication provides case studies and how to procedures that show backup and recovery scenarios This publication provides information about how to protect data in an SAP HANA environment by using IBM Spectrum Protect and IBM Spectrum Copy Data Manager This publication focuses on the data protection solution which is described through several scenarios The information in this publication is distributed on an as is basis without any warranty that is either expressed or implied Support assistance for the use of this material is limited to situations where IBM Spectrum Scale or IBM Spectrum Protect are supported and entitled and where the issues are specific to a blueprint implementation The goal of the publication is to describe the best aspects and options for backup snapshots and restore of SAP HANA Multitenant Database Container MDC single and multi tenant installations on IBM Power Systems by using theoretical knowledge hands on exercises and documenting the findings through sample scenarios This document provides resources about the following processes Describing how to determine the best option including SAP Landscape aspects to back up snapshot and restore of SAP HANA MDC single and multi tenant installations based on IBM Spectrum Computing Suite Red Hat Linux Relax and Recover ReAR and other products Documenting key aspects such as recovery time objective RTO and recovery point objective RPO backup impact load duration scheduling quantitative savings for example data deduplication integration and catalog currency and tips and tricks that are not covered in the product documentation Using IBM Cloud Object Storage and documenting how to use IBM Spectrum Protect to back up to the cloud SAP HANA 2 0 SPS 05 has this feature that is built in natively IBM Spectrum Protect for Enterprise Resource Planning ERP has this feature too Documenting Linux ReaR to cover operating system OS backup because ReAR is used by most backup products such as IBM Spectrum Protect and Symantec Endpoint Protection SEP to back up OSs This publication targets technical readers including IT specialists systems architects brand specialists sales teams and anyone looking for a guide about how to implement the best options for SAP HANA backup and recovery on IBM Power Systems Moreover this publication provides documentation to transfer the how to skills to the technical teams and solution guidance to the sales team This publication complements the documentation that is available at IBM Knowledge Center and it aligns with the educational materials that are provided by IBM Garage™ for Systems Technical Education and Training

**NARCISSISTIC ABUSE RECOVERY - RECLAIM YOUR MIND AND POWER** JONATHAN

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Reclaiming Power in Congregational and Community Ministry Fritz Ritsch,2023-11-14 Partisan religious interests have highjacked faith in America for political power in the process dividing our nation and giving religion a bad name Faith groups who want to build unity in contrast feel powerless to attain their goals Congregations who can adapt to a more democratic approach to ministry in which power is shared by both staff and congregants can dramatically strengthen their congregations and serve their neighbors more effectively Shared power strengthens individuals congregations and community efforts enabling us to work with others build community and recognize and overcome negative power dynamics so that people can work together to build healthier congregations and communities It also burnishes religion s tarnished image by demonstrating faithful cooperative and positive civic engagement for the community s good This book also addresses the inevitable power dynamics in any congregation allowing leaders to recognize unhealthy dynamics foster healthy ones and discover and cultivate the hidden power in each parishioner so that individually they can live more fully into God s intention for them and together the congregation can become the outpost of God s reign that it is meant to be

**Addiction, Attachment, Trauma and Recovery: The Power of Connection (Norton Series on Interpersonal Neurobiology)** Oliver J. Morgan,2019-10-01 2020 Award Winner for the Independent Press Award in the category of Addiction Recovery A new model of addiction that incorporates neurobiology social relationships and ecological systems Understanding addiction is no longer just about understanding neurons or genes broken brain functioning learning or faulty choices Oliver J Morgan provides a fresh take on addiction and recovery by presenting a more inclusive framework than traditional understanding Cutting edge work in attachment interpersonal neurobiology and trauma is integrated with ecological systems thinking to provide a consilient and comprehensive picture of addiction Humans are born into connection and require nourishing relationships for healthy living Adversities however bring fragmentation and create the conditions for

ill health They create vulnerabilities In order to cope individuals can turn to alternatives substitute relationships that ease the pain of disconnection These can become addictions Addiction Attachment Trauma and Recovery presents a model a method and a mandate This new focus calls for change in the established ways we think and behave about addiction and recovery It reorients understanding and clinical practice for mental health and addiction counselors psychologists and social workers as well as for addicts and those who love them Comparative Evaluation of Three Alternative Power Cycles for Waste Heat Recovery from the Exhaust of Adiabatic Diesel Engines M. Murray Bailey,1985 **A Navigational Aid to Recovery , Stall Recovery and Stall Warning Instrumentation in a Light Airplane** Phillip Justin Rulon,Kenneth W. Vaughn,1950 *Thermal Cycles of Heat Recovery Power Plants* Tangellapalli Srinivas,2021-04-02 Thermal Cycles of Heat Recovery Power Plants presents information about thermal power plant cycles suitable for waste heat recovery WHR in modern power plants The author covers five thermal power cycles organic Rankine cycle ORC organic flash cycle OFC Kalina cycle KC steam Rankine cycle SRC and steam flash cycle SFC with the working fluids of R123 R124 R134a R245fa R717 and R407C The handbook helps the reader to understand the latest power plant technologies suitable for utilizing the waste heat generated by thermal industrial processes Key Features Comprehensive modeling simulation analysis and optimization of 5 power cycle types with different working fluids Clear information about the processes and solutions of thermal power cycles to augment the power generation with improved energy conversion Simple reader friendly presentation bibliographic references after each chapter for further reading This handbook is suitable for engineering students in degree courses and professionals in training programs who require resources on advanced thermal power plant operation and optimal waste heat recovery processes respectively It is also a handy reference for energy conversion efficiency in heat recovery power plants The book is also of interest to any researchers interested in industrial applications of thermodynamic processes **IBM Power Systems High Availability and Disaster Recovery Updates: Planning for a Multicloud Environment** Dino Quintero,Thomas Baumann,Vera Cruz,Nilabja Haldar,Youssef Largou,Prashant Pandey,Edson Gomes Pereira,Diego Riesco,Douglas Roach,Antony Steel,IBM Redbooks,2022-05-27 This IBM Redpaper publication delivers an updated guide for high availability and disaster recovery HADR planning in a multicloud environment for IBM Power This publication describes the ideas from studies that were performed in a virtual collaborative team of IBM Business Partners technical focal points and product managers who used hands on experience to implement case studies to show HADR management aspects to develop this technical update guide for a hybrid multicloud environment The goal of this book is to deliver a HADR guide for backup and data management on premises and in a multicloud environment This document updates HADR on premises and in the cloud with IBM PowerHA SystemMirror IBM VM Recovery Manager VMRM and other solutions that are available on IBM Power for IBM AIX IBM i and Linux This publication highlights the available offerings at the time of writing for each operating system OS that is supported in IBM Power including best practices This book addresses topics for IT architects IT

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