E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23 January 2025
PTDI, UiTM Cawangan Johor Kampus Pasir Gudang

e ISBN 978-967-0033-34-1

ORGANIZED BY:

Electrical Engineering Studies, College of Engineering
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang
https://tiec-uitmpg.wixsite.com/tiec

E-PROCEEDINGS
of International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23rd JANUARY 2025
PTDI, UiTM Cawangan Johor, Kampus Pasir Gudang

Organized by

Electrical Engineering Studies, College of Engineering,

Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang.

https://tiec-uitmpg.wixsite.com/tiec

Editors

Aznilinda Zainuddin

Maisarah Noorezam

e ISBN: 978-967-0033-34-1

Published in Malaysia by
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang, 81750 Masai

A-ST060: INNOVATIVE POWER GRID SOLUTIONS: STRENGTHENING RESILIENCE AGAINST DISRUPTIONS

Fathiah Zakaria, Ismail Musirin, Norziana Aminudin and Dalina Johari
Centre for Electrical Engineering Studies, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

Corresponding author: Ismail Musirin, ismailbm@uitm.edu.my

ABSTRACT

The resilience of power systems against disruptive events, such as hurricanes, is crucial for ensuring stability and reliability. This study introduces the Evolutionary Chaotic Cloning-Squirrel Algorithm (ECCSA), an innovative optimization technique designed to enhance power system resilience through optimized load-shedding strategies. ECCSA integrates chaotic dynamics and clonal selection principles with the Squirrel Search Algorithm to address limitations in traditional optimization methods, such as entrapment in local optima, thereby improving solution accuracy and efficiency. The proposed framework was applied to the IEEE 57-Bus Reliability Test System, analyzing two hurricane scenarios with varying reactive power demands. ECCSA demonstrated its ability to determine optimal load-shedding locations and sizes, significantly reducing power losses and improving resilience indices. For example, at Bus 33, power losses were reduced by 40.17% in Scenario 2, with resilience indices improving notably. The uniqueness of ECCSA lies in its hybrid optimization approach, adaptability to dynamic conditions, and effectiveness in minimizing transmission losses. Socio-economically, it ensures reliable power delivery, supports renewable energy integration, and reduces the environmental impact of power outages. Its scalability and cost-effectiveness present strong commercialization prospects, making ECCSA a robust solution for modernizing power grids and addressing the growing demand for resilient energy systems.

Keywords: Load-Shedding Optimization, Power System Resilience, Evolutionary Chaotic Cloning-Squirrel Algorithm (ECCSA), IEEE 57-Bus RTS

1. Product Description

The Evolutionary Chaotic Cloning-Squirrel Algorithm (ECCSA) is an advanced optimization framework designed to enhance power system resilience against disruptive events, such as hurricanes. By combining chaotic dynamics, clonal selection principles, and the Squirrel Search Algorithm, ECCSA overcomes limitations of traditional optimization methods, such as local optima entrapment, ensuring precise and efficient solutions for load-shedding strategies. ECCSA's unique features include its ability to determine optimal load-shedding locations and capacities, significantly reducing power losses and improving system resilience. Applied to the IEEE 57-Bus Reliability Test System, ECCSA demonstrated its effectiveness by reducing power losses by up to 40.17% and enhancing resilience indices in critical scenarios. Its adaptability to dynamic conditions and varying operational demands make it a robust tool for modern grid management. The product’s socio-economic and environmental impact lies in its ability to ensure reliable power delivery, particularly during extreme events, while supporting renewable energy integration and reducing greenhouse gas emissions. This promotes energy security, minimizes outage costs, and supports sustainable development. With scalability and cost-effectiveness, ECCSA presents strong commercialization prospects as a reliable, data-driven solution for utility providers, offering a competitive edge in modernizing grids and addressing the growing global demand for resilient and sustainable energy systems.

2. Method Flow Chart and Model Description

The study evaluates power system resilience under hurricanes using the IEEE 57-Bus RTS. The system is divided into two regions to mimic real-world transmission systems.

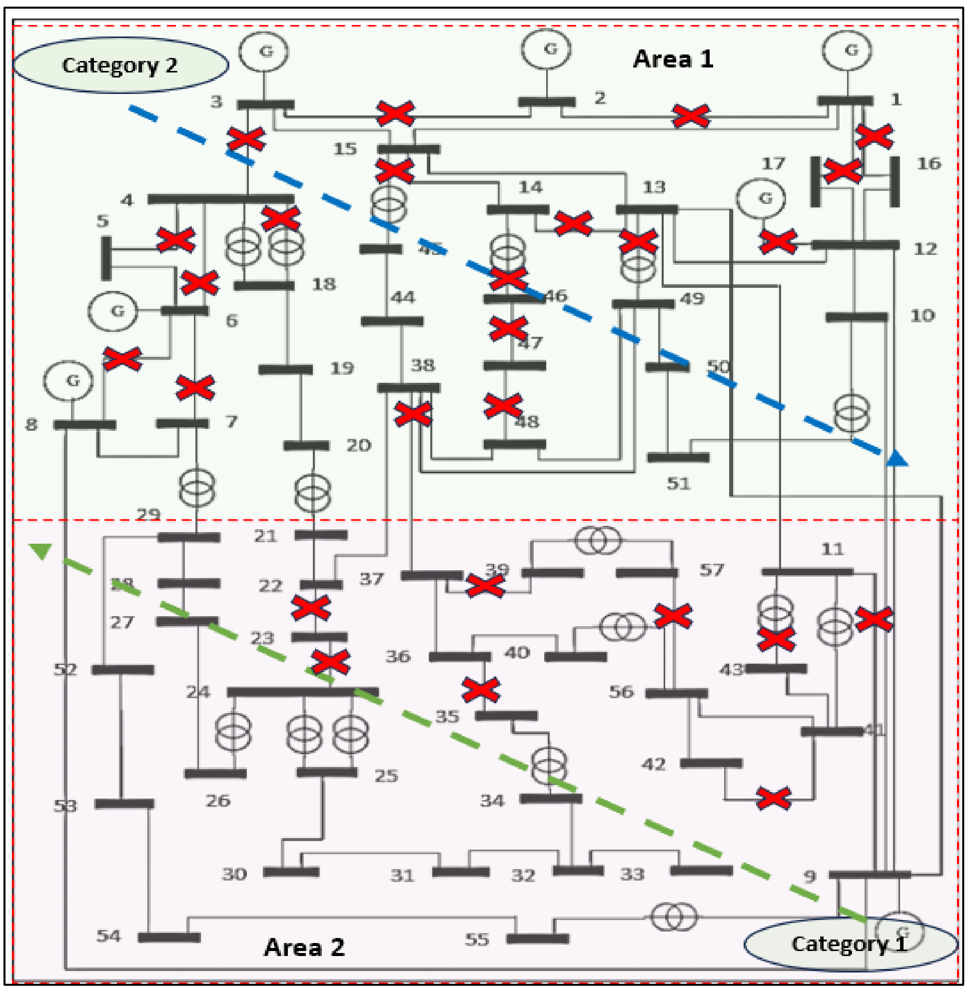

Figure 1. Impact of Hurricanes on the IEEE 57-Bus RTS: Zones and Patterns

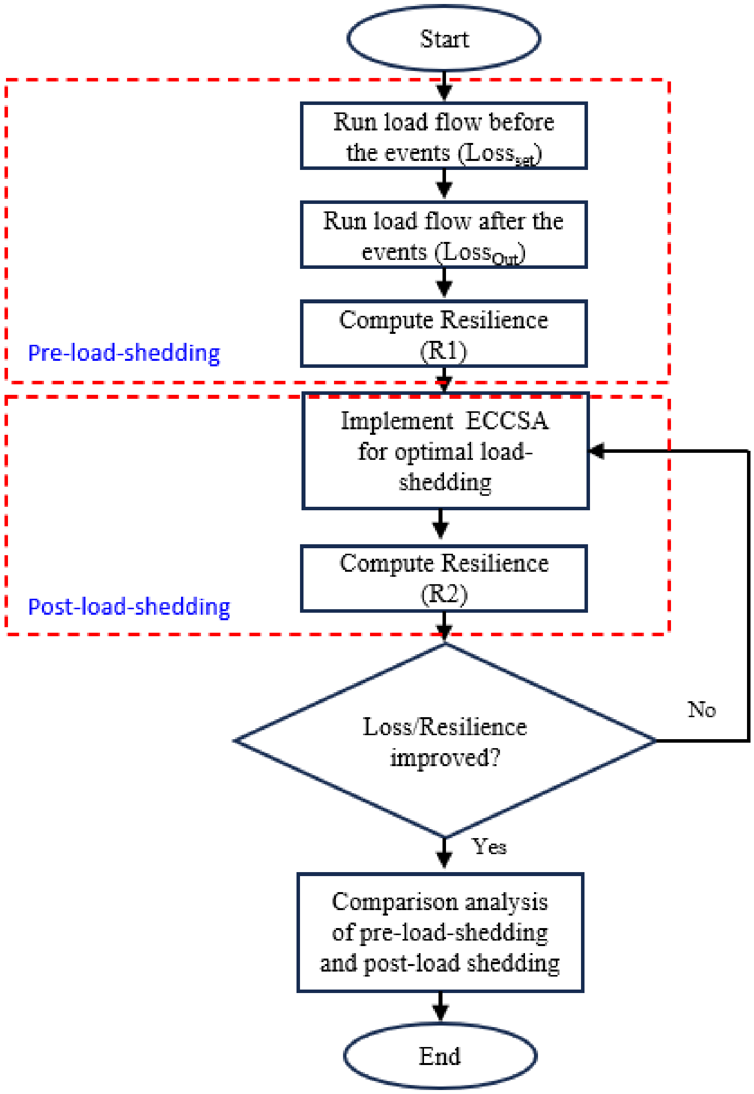

Figure 2. ECCSA Flowchart

Figure 1 hurricane patterns and **Figure 2** illustrates the optimization flowchart. A new ECCSA algorithm, combining CSO, SSA, and EP, addresses local optima challenges. The process involves two stages: pre-load-shedding and post-load-shedding. Initially, system losses and resilience (R1) are calculated under normal and disrupted conditions. ECCSA then optimizes load-shedding, reducing losses and improving resilience (R2). Results are iteratively refined until improvements are achieved. **Table 1** shows baseline losses, outage impacts, and post-optimization results. For example, Bus 31's losses at 15 MVAr drop from 42.753 MW to 32.215 MW, with resilience improving from 2.508 to 3.057. The ECCSA demonstrates significant loss reduction and resilience enhancement.

TABLE 1. Numerical results of scenario 1

SCENARIO 1									
BUS		***31***			***32***			***33***	
Q_D (MVAR)	***5***	***10***	***15***	***5***	***10***	***15***	***5***	***10***	***15***
$LOSS_{SET}$ (MW)	28.464	29.220	30.565	28.667	29.424	30.661	28.557	29.298	
$LOSS_{OUT}$ (MW)	32.850	34.413	42.753	33.254	34.836	39.148	33.031	34.512	37.997
$LOSS_{LS}$ (MW)	29.485	31.231	32.215	29.997	31.852	32.541	31.254	32.514	32.614
R1	6.488	5.627	2.508	6.250	5.437	3.613	6.382	5.618	4.101
R2	8.762	9.816	3.057	9.213	10.676	4.926	17.587	16.271	6.059
LOC_1	8	21	21	10	5	9	10	8	15
LOC_2	5	5	5	8	9	5	13	5	7
LOC_3	6	13	13	7	12	13	5	21	6
PD_1	65.75	74.44	107.10	31.97	112.40	59.57	70.28	46.98	37.51
PD_2	150.54	167.95	75.69	61.78	139.98	140.67	44.10	133.32	51.34
PD_3	57.48	29.35	48.95	73.51	63.58	39.55	150.83	51.21	50.49
QD_1	98.60	34.71	26.10	41.47	139.84	75.43	157.97	64.35	15.83
QD_2	27.42	119.45	13.25	99.12	26.89	90.27	61.78	41.47	34.71
QD_3	46.36	181.46	43.97	73.51	63.58	39.55	83.89	41.94	111.52

3. Novelty and uniqueness

The Evolutionary Chaotic Cloning-Squirrel Algorithm (ECCSA) is a groundbreaking optimization framework designed to address the critical challenges of power system resilience in the face of disruptive events. Its novelty lies in the integration of chaotic dynamics, clonal selection principles, and the Squirrel Search Algorithm into a cohesive approach. This hybridization allows ECCSA to overcome common limitations of traditional optimization methods, such as local optima entrapment, and deliver superior accuracy and efficiency in solving complex power system challenges. What sets ECCSA apart is its ability to dynamically adapt to varying system conditions and operational demands, ensuring optimal load-shedding strategies during extreme events. Unlike conventional algorithms, ECCSA incorporates a resilience-focused approach, quantifying system performance before and after optimization, and targeting critical areas for intervention. The uniqueness of ECCSA is demonstrated in its application to the IEEE 57-Bus Reliability Test System, where it significantly reduced power losses and enhanced resilience indices under various scenarios. This innovative algorithm not only ensures reliable power delivery but also supports the integration of renewable energy sources, promoting sustainability. Its scalability and versatility make it a pivotal solution for modernizing power grids, providing a unique combination of precision, adaptability, and robust performance for future energy systems.

4. Benefit to mankind

The ECCSA enhances power system resilience and reliability, ensuring critical services like healthcare and communication remain operational during disruptions such as hurricanes. By optimizing load-shedding strategies, it minimizes the socio-economic impact of outages. ECCSA promotes sustainability by supporting renewable energy integration, reducing reliance on fossil fuels, and lowering greenhouse gas emissions, contributing to climate change mitigation and a cleaner environment. Its scalability and adaptability make it suitable for diverse conditions, including Malaysia's flood-prone regions, ensuring reliable energy distribution during natural disasters. ECCSA's efficiency in reducing power losses and improving resilience indices benefits both urban and rural populations by providing stable and equitable energy access. Moreover, its cost-effective approach empowers utility providers to modernize grids while fostering a sustainable energy future. This innovative algorithm addresses global energy challenges, offering a robust solution for resilient, reliable, and environmentally friendly power systems.

5. Innovation and Entrepreneurial Impact

The ECCSA is an innovative optimization framework that revolutionizes power system resilience by integrating chaotic dynamics, clonal selection principles, and the Squirrel Search Algorithm. This advanced methodology ensures precise load-shedding strategies, overcoming challenges like local optima entrapment and enhancing system reliability during disruptive events. ECCSA's adaptability to dynamic conditions, coupled with its ability to reduce power losses and improve resilience indices, highlights its groundbreaking impact. By supporting renewable energy integration and minimizing environmental impact, it aligns with global sustainability goals, making it an essential tool for modern grid management. From an entrepreneurial perspective, ECCSA offers substantial commercialization opportunities. Its scalability, cost-effectiveness, and robust performance make it a valuable asset for utility providers seeking to modernize power grids and enhance operational efficiency. This innovation positions businesses at the forefront of the energy sector, driving sustainable development and addressing the global demand for resilient energy systems.

6. Potential commercialization

The ECCSA holds significant commercialization potential in the energy sector. As a cost-effective, scalable, and adaptable solution, it optimizes load-shedding strategies and enhances power system resilience, making it highly valuable for utility providers and energy companies. ECCSA reduces power losses and improves resilience indices under dynamic and extreme conditions, supporting renewable energy integration and aligning with global sustainability goals. Its versatility across grid sizes and configurations ensures adoption in both urban and rural areas. The algorithm's market readiness is supported by its copyright certification and registration with MyIPO, Malaysia, ensuring intellectual property protection. Further establishing its credibility, ECCSA won the Gold Award in the Semarak

International Research Article Competition 2024 (SIRAC) and is advancing toward journal publication. Additionally, it has practical applications in Malaysia, particularly in managing energy systems during flood disasters, positioning it as a groundbreaking innovation for resilient and sustainable energy systems.

7. Authors' Biography

Fathiah Zakaria received her Bachelor's degree (Hons) in Electrical & Electronics Engineering from Universiti Teknologi Petronas (UTP) in 2008 and her MSc in Electrical Engineering from Universiti Teknologi MARA (UiTM) in 2014. She is currently pursuing a PhD in Electrical Engineering, specializing in power system, at UiTM Shah Alam, Malaysia. Since 2014, she has been a lecturer at UiTM. Her research interests include artificial intelligence, optimization, and power system.

Prof. Ir. Dr. Ismail Bin Musirin obtained Bachelor of Electrical Engineering (Hons) in 1990 from Universiti Teknologi Malaysia, MSc in Pulsed Power Technology in 1992 from University of Strathclyde, United Kingdom and PhD in Electrical Engineering from Universiti Teknologi MARA (UiTM), Malaysia in 2005. He is currently a Professor of Power System at the School of Electrical Engineering, College of Engineering, UiTM and headed the Power System Operation (POSC) Computational Intelligence Research Group. His research interest includes Power System Stability, Distributed Generation Optimization, Artificial Intelligence Applications, Optimization Algorithms Derivations and Machine Learning Applications.

Dr. Norziana Aminudin is a Senior Lecturer at Universiti Teknologi MARA (UiTM) Shah Alam and an active member of the Power System Operation Computational Intelligence Research Group at UiTM. Her research focuses on artificial intelligence, with expertise in optimization techniques, machine learning, and risk assessment in power systems. Since 2007, she has contributed extensively to the field through numerous journal publications and conference papers, advancing innovative solutions for modern power system challenges.

D. Johari received her PhD degree in Engineering Sciences with Specialization in Atmospheric Discharges from Uppsala University, Sweden in 2017. She obtained her MSc degree in Electrical Engineering from Universiti Teknologi MARA (UiTM), Malaysia in 2008 and B.Eng. in Electrical Engineering (Hons) from the University of Liverpool, UK in 1999. She worked as an operation & maintenance engineer from 2000 to 2003 and continued as a senior planning engineer until 2005. D. Johari now serves as a senior lecturer at UiTM, Shah Alam, Malaysia. She is also a graduate member of the Board of Engineers Malaysia (BEM). Her research interests includes lightning physics, lightning protection, lightning prediction, high voltage engineering, power system and artificial intelligence. She be contacted at dalinaj@uitm.edu.my.