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ENHANCING POWER SYSTEM SECURITY WITH A HYBRID SATS ALGORITHM FOR OPTIMAL POWER FLOW

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ABSTRACT

The security and performance of electricity systems are the primary concerns in their planning and operation. It is imperative to establish appropriate procedures for the maintenance and enhancement of security within the power system. This research introduces a hybrid simulated annealing and tabu search (Hybrid SATS) approach to address the security-constrained optimal power flow problem. The main aim of the research is to improve power system security and reduce generator fuel expenses. Contingency ranking is employed to determine line outages. The Hybrid SATS approach effectively alleviates line flow limit breaches during various single line outages, maintaining power flows within secure parameters. To evaluate the efficacy of the proposed Hybrid SATS approach, simulation experiments are conducted on the standard IEEE 30 bus, and the results are compared with those of the SA and TS methods.

Keywords: *Security Constrained Optimal Power Flow, Simulated Annealing, Tabu Search, Contingency.*

1. INTRODUCTION

The proper operation and execution of huge power systems have become increasingly difficult due to high power demand. It emphasizes the significance of a safe, secure, and stable electricity system. It is imperative to implement appropriate strategies for the maintenance and enhancement of security inside the power system. Recent research indicate that power flow violations can be mitigated and the security of the power system can be improved. The objective of optimal power flow (OPF) is to optimize a designated objective function while ensuring the economic costs and security of a power system are met.

This research proposes a Hybrid SATS algorithm to enhance power system security by optimizing power flow while minimizing generator fuel costs. Unlike conventional methods, the hybrid approach effectively mitigates line flow limit violations under contingency scenarios. The study's novelty lies in integrating Simulated Annealing (SA) and Tabu Search (TS) for improved convergence, robustness, and computational efficiency. The outcome measures include enhanced voltage stability, reduced power losses, and improved security-constrained optimal power flow (SCOPF) performance, validated through comparative analysis on IEEE test systems.

Recently, many mathematical programming techniques, including the Newton method, gradient method, and interior point method, have been employed to address the OPF problem. Nonetheless, the Newton approach is constrained by the continuity of the problem formulation and restrictions; the gradient method exhibits suboptimal convergence properties, while the interior point method is time-intensive and converges to local optima. Typically, traditional optimization techniques account for the initially designated point and convexity to get a global optimal solution; however, the OPF issue is non-convex and has multiple local minima.

In recent years, heuristic optimization methods have been developed to address the limitations of standard optimization algorithms. The principal heuristic optimization methods of recent times for addressing the OPF problem include Evolutionary Programming (EP) [1], Genetic Algorithm (GA) [2], Particle Swarm Optimization (PSO) [3], Simulated Annealing (SA) [4],[5], and Tabu Search (TS) [6],[7]. These optimization strategies are investigated to identify the global optimum for any objective function and associated restrictions. In most optimization approaches, the inappropriate selection of specific control parameters adversely impacts the algorithm's efficiency regarding solution quality and convergence characteristics.

Additionally, different hybrid algorithms that integrate multiple methods have been proposed to enhance search efficiency and increase the quality of solutions for optimization problems. A hybrid particle swarm optimization algorithm (HPSO) approach is utilized to solve the discrete optimal power flow (OPF) problem and handling inequality constraint improvement in [8]. A hybrid differential evolution combined with particle swarm optimization is utilized to improve the maximum loadability limit of the power system in [9]. A hybrid imperialist competitive-sequential quadratic programming (HIC-SQP) technique for addressing economic load dispatch while integrating stochastic wind power is proposed in[10]. In [11], a hybrid fuzzy system particle swarm optimization and Nelder-Mead algorithm (HFPSO-NM) are utilized to address the optimal power flow (OPF) in both normal and contingency operational scenarios. A hybrid Nelder–Mead simplex-based firefly algorithm for addressing efficient reactive power dispatch is suggested in [12].

Security constrained optimal power flow (SCOPF) is an optimal power flow formulation that accounts for the operational contingencies of the power system. Security-constrained optimal power flow is a crucial study domain for improving the security of operational power systems. Diverse methodologies have been suggested to address the SCOPF problem. A modified bacterium foraging method is proposed in [13] for addressing the security-constrained optimal power flow, taking into account wind and thermal generation. A contingency partitioning method for the computation of preventive-corrective security constrained optimal power flow is proposed in [14]. A Fuzzy Harmony Search Algorithm is utilized to improve power system security in [15]. A hybrid PSO-APO algorithm is suggested in [16] for addressing the security-constrained optimal power flow, incorporating both wind and thermal generators.

This work proposes a hybrid simulated annealing and tabu search (Hybrid SATS) approach to address the security-constrained optimal power flow problem. This Hybrid SATS method integrates both Simulated Annealing and Tabu Search techniques to achieve an effective optimal solution in a little duration. The main aim of the research is to improve power system security and reduce generator fuel expenses. Contingency ranking is employed to determine line outages. The Hybrid SATS approach efficiently alleviates line flow restriction violations during various single line outages, maintaining power flows within respective security thresholds. To evaluate the efficacy of the proposed Hybrid SATS approach, simulation experiments are conducted on the standard IEEE 30 bus, and the results are compared with those of the SA and TS methods.

The research focuses on enhancing power system security through a Hybrid SATS algorithm for solving the security-constrained optimal power flow (SCOPF) problem. The study assumes a balanced three-phase operation, deterministic load demand, and steady-state conditions while neglecting transient stability and dynamic faults. It primarily evaluates the effectiveness of the proposed approach using standard IEEE test systems. Transmission failures are considered within a contingency ranking framework but are not dynamically modeled. These refinements ensure a well-defined research scope and highlight the study's practical applicability.

The increasing complexity of modern power systems necessitates advanced optimization techniques for security-constrained optimal power flow (SCOPF). Traditional methods often struggle with computational efficiency and robustness, particularly under contingency scenarios. Existing metaheuristic approaches, such as Simulated Annealing (SA) and Tabu Search (TS), tend to suffer from imbalanced exploration and exploitation, leading to suboptimal power flow solutions. To address these challenges, this study proposes a Hybrid SATS algorithm that combines the strengths of SA and TS to enhance convergence efficiency, robustness, and solution accuracy. The primary objectives include developing an efficient power flow optimization framework, performing a comparative analysis with conventional heuristic methods, and assessing the practical impact on modern smart grids by minimizing fuel costs and power losses. This research significantly contributes to improving the security and stability of contemporary power systems.

The subsequent portions of the paper are organized as follows. Section 2 provides an overview of the simulated annealing and tabu search methodologies. Section 3 delineates the methodology of the proposed Hybrid SATS algorithm for addressing the SCOPF problem. Section 4 delineates the outcomes of the suggested method, whereas Section 5 summarizes the conclusion.

2. VERVIEW OF SIMULATED ANNEALING AND TABU SEARCH

2.1 Simulated Annealing (SA)

Simulated Annealing (SA) is a stochastic search algorithm fundamentally based on the cooling process observed in metallurgy. It denotes the procedure of subjecting things to elevated temperatures, subsequently followed by a systematic reduction of temperature in increments till reaching the ambient condition. Simulated Annealing employs the Metropolis algorithm [4] for simulation, which evolves a system from a specified initial high temperature. The Metropolis algorithm, utilizing a high initial temperature, is employed to randomly explore the solution space. The sampling process is reiterated by lowering the temperature to achieve the global best solution.

2.2 Tabu Search (TS)

Tabu Search is a heuristic approach that has been utilized by numerous academics for various combinatorial issues over the years. The operator move is utilized by Tabu Search to define the neighborhood of a trial solution. It is an iterative process that seeks to identify and enhance problem solutions from an initial state to a superior one. It possesses the capability to evade local optima by employing flexibility to prevent cycling.

Recollection of search history. It employs tabu moves, a finite list of prohibited actions derived from recent search history. The constraints of the tabu list and the ambition criterion are fundamental elements of Tabu Search. Tabu list limits render certain moves prohibited by setting specific constraints upon them. In the procedure, the oldest attribute is discarded when a new attribute is added to the list. Determining the appropriate size of the tabu list is challenging. Nonetheless, the efficacy of problem resolution is contingent upon the dimensions of the tabu list. The fulfillment of the aspiration condition triggers a prohibited motion by superseding tabu constraints. The ambition criterion applied here overrides a move in tabu status if that move yields a superior solution compared to the preceding one.

3. HYBRID SIMULATED ANNEALING AND TABU SEARCH ALGORITHM

Both the Simulated Annealing (SA) and Tabu Search (TS) approaches are used into the Hybrid SATS method in order to rapidly arrive at an optimal solution that is both effective and efficient. Simulation Annealing, often known as SA, is a method of global optimization that accomplishes the task of reaching the global optimum in a very efficient manner. Nevertheless, simulated annealing necessitates a considerable amount of processing time, which leads to interruptions in the process of determining the optimal solution within a particular region. The result of this is that the local search method has been combined with the simulated annealing technique. Consequently, simulated annealing is responsible for locating the optimal region, which is then utilized by a local optimizer to ascertain the optimal solution.

For the purpose of carrying out local searches, the heuristic algorithm known as Tabu Search is applied. The intrinsic adaptive memory capability guarantees that solutions will not be repeated, which enables the search process to proceed until the ambition condition is satisfied.

For the purpose of solving the security-constrained optimal power flow problem, this study suggests a hybrid technique that combines simulated annealing and tabu search. Simulated Annealing (SA) and Tabu Search (TS) are both components of this hybrid approach, which aims to improve the quality of the answer. The findings reveal that there has been a major improvement, since SA has successfully identified an initial solution, which TS has then optimized until the termination criterion that was stated has been satisfied. An illustration of the flow chart for the Hybrid SATS approach may be found in Figure 1.

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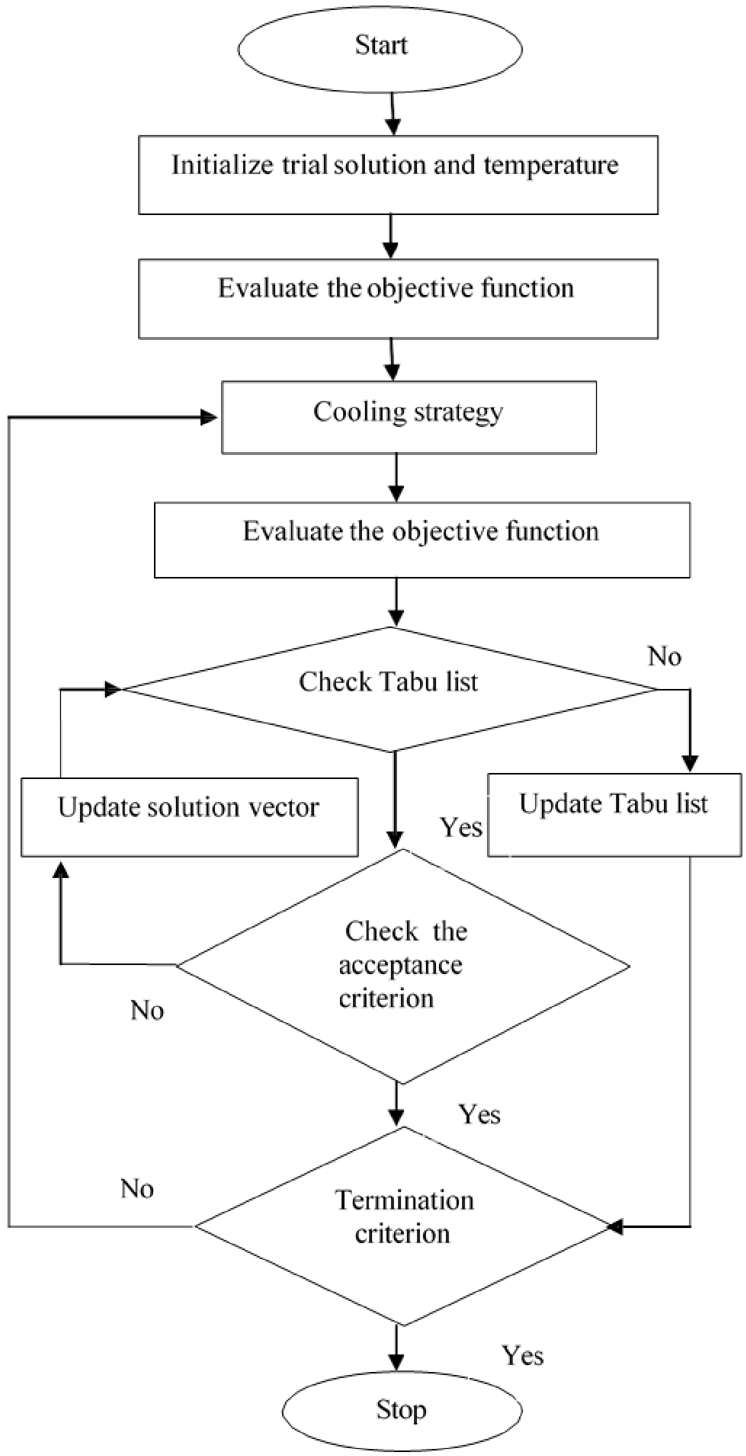

Figure 1: Flow chart of Hybrid SATS method

The superior performance in mitigating line flow limit violations, enhancing security-constrained optimal power flow (SCOPF), and achieving faster convergence compared to conventional Simulated Annealing (SA) and Tabu Search (TS) methods. However, a minus aspect is its relatively higher computational complexity, which may pose challenges for real-time implementation in large-scale power networks. Despite this, the interesting feature of the Hybrid SATS approach lies in its integration of SA and TS, which creates a balanced synergy between exploration and exploitation, leading to more robust and optimized solutions. This critical discussion, along with a comparative analysis of existing methods, establishes the novelty and effectiveness of the proposed approach in addressing power system security challenges.

Existing research on security-constrained optimal power flow (SCOPF) primarily relies on metaheuristic algorithms, such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Simulated Annealing (SA), and Tabu Search (TS). While these methods have shown effectiveness in addressing power flow optimization, they often face trade-offs between convergence speed, solution quality, and computational complexity.

For instance, GA and PSO are widely used for their global search capabilities but may struggle with premature convergence and require extensive parameter tuning. SA and TS, on the other hand, offer better local search capabilities but may become trapped in local minima. Recent studies have attempted hybridization, but most lack a systematic integration that balances exploration and exploitation effectively. The proposed Hybrid SATS algorithm addresses these gaps by leveraging SA's probabilistic exploration and TS's structured memory, ensuring better solution stability and accuracy. The research follows a structured methodology to ensure repeatability. The Hybrid SATS algorithm optimizes security-constrained optimal power flow (SCOPF) by combining Simulated Annealing (SA) and Tabu Search (TS). It undergoes contingency analysis (N-1 ranking) and is tested on the IEEE 30-bus system, comparing results with SA and TS.

4. SIMULATION RESULTS AND DISCUSSION

The proposed hybrid algorithm for addressing the security constrained optimal power flow problem is evaluated on the standard IEEE 30 bus system and implemented using MATLAB software. The IEEE 30 bus system comprises six generators, forty-one transmission lines, and four tap-changing transformers. The data for the IEEE 30 bus utilized in this study are sourced from [17]-[19].

To illustrate the efficacy of the proposed hybrid algorithm, two scenarios are examined in the simulation studies: the base case condition and the contingency condition, specifically the outage of line 2-5, which represents the most severe contingency in the IEEE 30 bus system. The parameters for the proposed method are established as follows: initial temperature = 5000 °C, reduction rate = 0.85, number of trial solutions = 20, and size of the tabu list = 10.

Table 1: Optimal control variables settings for base case condition

Control Variables		SA	TS	Hybrid SATS
P_G (MW)	P_{G1}	178.12	176.71	176.91
	P_{G2}	46.81	51.06	47.67
	P_{G5}	21.15	22.84	21.94
	P_{G8}	16.09	15.98	21.47
	P_{G11}	14.29	12.73	12.24
	P_{G13}	16.92	13.80	12.59
V (p.u.)	V_1	1.0500	1.0500	1.0500
	V_2	1.0333	1.0330	1.0382
	V_5	1.0516	1.0006	1.0147
	V_8	1.0266	1.0000	1.0180
	V_{11}	1.0980	1.0488	1.0892
	V_{13}	1.0081	1.0952	1.1000
Tap (p.u.)	$T_{6,9}$	0.9321	0.9476	1.0165
	$T_{6,10}$	1.0376	0.9498	0.9314
	$T_{4,12}$	1.0849	1.0219	0.9901
	$T_{28,27}$	0.9561	0.9308	0.9457
Cost ($/hr)		804.93	803.40	802.21
Power Loss (MW)		9.98	9.72	9.42
CPU Time (sec)		125.39	83.75	65.04

Table 2: Comparison of generator fuel cost with other optimization methods for base case condition

Optimization method	Generator Fuel cost ($/h)
NLP [17]	802.4
EP [1]	802.62
GA [2]	803.05
IEP [18]	802.46
DE [19]	802.39
MDE [19]	802.37
SA	804.93
TS	803.4
Hybrid SATS	802.21

Table 3: Optimal control variables settings under contingency condition with line 2-5 outage

Control Variables	SA	TS	Hybrid SATS

$P_G(MW)$	P_{G1}	173.55	176.31	171.48
	P_{G2}	32.75	46.94	47.75
	P_{G5}	20.95	26.48	25.84
	P_{G8}	32.30	22.38	27.64
	P_{G11}	26.87	12.25	13.23
	P_{G13}	13.80	15.15	12.74
V (p.u)	V_1	1.0500	1.0500	1.0500
	V_2	1.0396	1.0479	1.0541
	V_5	0.9774	0.9846	0.9910
	V_8	1.0736	1.0401	1.3514
	V_{11}	0.9507	1.0271	1.1000
	V_{13}	1.0501	1.0000	1.1000
Tap (p.u.)	$T_{6,9}$	1.0295	1.0755	1.0654
	$T_{6,10}$	1.0621	1.0706	0.9489
	$T_{4,12}$	0.9369	0.9812	1.0305
	$T_{28,27}$	0.9262	0.9724	0.9604
Cost ($/hr)		843.01	828.79	826.81
Power Loss (MW)		16.82	16.11	15.28
CPU Time (sec)		133.53	129.25	65.7

4.1 Fundamental condition

Table 1 presents the optimal settings for control variables under the base case condition. Table 1 indicates that the minimum generator fuel cost achieved via the Hybrid SATS algorithm is 802.21 $/h, which is lower than the costs obtained using the SA and TS methods. The Hybrid SATS algorithm requires less computing time to derive the optimal solution compared to Simulated Annealing (SA) and Tabu Search (TS). All derived solutions satisfy the constraints on control variables and the limits of transmission line flow. Table 2 presents a comparison of generator fuel costs with various optimization methods under base case conditions. Table 2 illustrates the effectiveness of the proposed Hybrid method in reducing generator fuel costs.

4.2 Contingency condition

The contingency ranking method [20] identifies the line 2-5 outage as the most severe contingency, resulting in overloading on lines 2-6 and 5-7, thereby impacting the security of the power system. This paper examines the line 2-5 outage for the purpose of security assessment. If the proposed method alleviates line overload during the most severe contingency, it is likely to alleviate overloaded lines during less severe contingencies as well.

Table 3 presents the optimal settings for control variables under contingency conditions with the outage of line 2-5. Table 4 presents the line flow limit violations that occur under contingency conditions due to the outage of line 2-5. Tables 3 and 4 indicate that the minimum generator fuel cost achieved with the Hybrid SATS algorithm is 826.81 $/h, which is lower than that obtained using SA and TS. Lines 2-6 and 5-7 exhibit overload across all methods, as illustrated in Figure 2.

Table 4: Line flow limit violations under contingency condition with line 2-5 outage

Line between buses	Line flow limit (MVA)	Line flow (MVA)		
		SA	TS	Hybrid SATS
2-6	65	68.21	72.89	66.24
5-7	70	76.62	75.14	71.24

Table 5: Optimal control contingency condition with function) variables settings under line 2-5 outage (with penalty

Control Variables		SA	TS	Hybrid SATS
$P_G(MW)$	P_{G1}	148.46	172.48	150.47
	P_{G2}	32.82	48.13	29.23
	P_{G5}	45.58	26.49	35.75
	P_{G8}	13.15	25.14	21.09
	P_{G11}	23.39	11.73	27.42
	P_{G13}	31.34	14.87	32.08
V (p.u.)	V_1	1.0500	1.0500	1.0500
	V_2	1.0185	1.0404	1.0400
	V_5	0.9732	0.9755	0.9906
	V_8	0.9822	1.0197	1.0141
	V_{11}	1.0981	1.0902	1.0006
	V_{13}	1.0951	1.1000	1.0000
Tap (p.u.)	$T_{6,9}$	1.0083	1.0106	1.0594
	$T_{6,10}$	0.9490	0.9091	1.0511
	$T_{4,12}$	1.0313	0.9492	0.9848
	$T_{28,27}$	1.0306	0.9705	1.0662
Cost ($/hr)		877.89	827.37	862.85
Power Loss (MW)		11.34	15.44	12.64
CPU Time (sec)		163	125.26	67.85

Table 5 presents the optimal control variable settings under contingency conditions, specifically for the line 2-5 outage, incorporating a penalty function. The line flow limit during contingency conditions, specifically with the outage of line 2-5

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(incorporating the penalty function), is presented in Table 6.

Tables 5 and 6 demonstrate that generation rescheduling occurs across all methods, with overloaded lines 2-6 and 5-7 being alleviated solely by the SA and Hybrid SATS methods. Notably, the generator fuel cost achieved through the Hybrid SATS method is lower than that obtained via the SA method. The TS method yields the lowest generator fuel cost relative to SA and Hybrid SATS; however, lines 2-6 and 5-7 experience overload, as illustrated in Figure 3. The Hybrid SATS method requires less computing time to derive the optimal solution compared to Simulated Annealing (SA) and Tabu Search (TS).

Consequently, the Hybrid SATS method yields improved and satisfactory results. The Hybrid SATS method demonstrates effectiveness in addressing the SCOPF problem by achieving the specified objectives while adhering to constraints on control variables and transmission line flow limits. The Hybrid SATS method has been demonstrated to improve power system security during contingency conditions.

Table 6. Line flow limit under contingency condition with line 2-5 outage (with penalty function)

Line between buses	Line flow limit (MVA)	Line flow (MVA)		
		SA	TS	Hybrid SATS
2-6 5-7	65 70	62.59 68.32	72.14 73.59	63.89 68.49

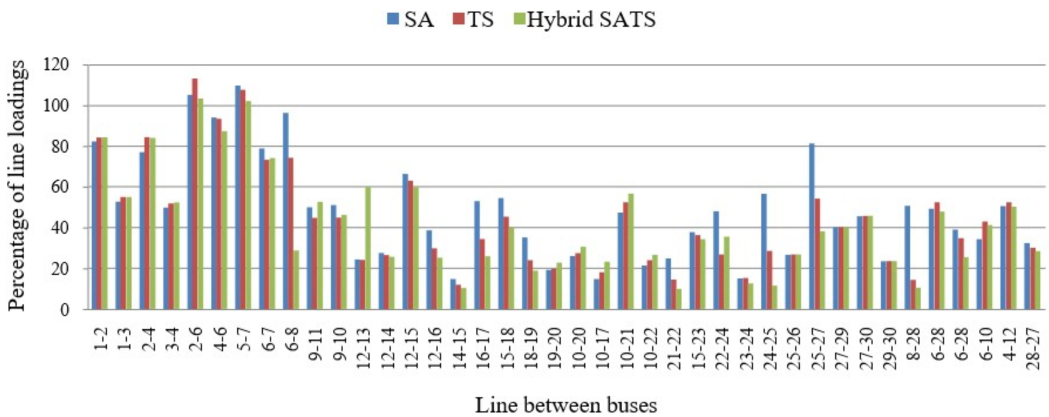

Figure 2: Line flows under contingency condition with line 2-5 outage

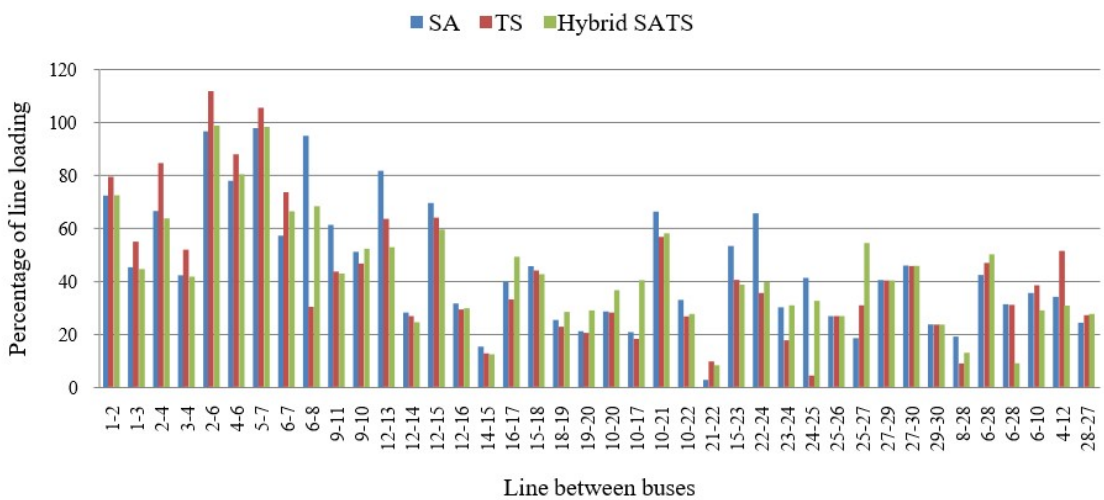

Figure 3: Line flows under contingency condition with line 2-5 outage (with penalty function)

5. CONCLUSION

This paper presents a Hybrid SATS algorithm designed to address the security-constrained optimal power flow problem. This algorithm integrates simulated annealing and tabu search methods to achieve an effective optimal solution in a brief period. The main aim of this study is to improve power system security and reduce generator fuel costs. The simulation studies consider both the base case condition and the most severe contingency condition. A solution is proposed under contingency conditions, with the objective function augmented by a penalty function to mitigate overload. The simulation results from the IEEE 30 bus system illustrate the efficacy of the proposed hybrid method. Consequently, this approach yields the lowest generator fuel cost relative to alternative optimization methods and operates efficiently. Improves the security of power systems during contingency conditions. Future work may be expanded through the integration of FACTS devices.

This research introduces a Hybrid SATS algorithm, integrating Simulated Annealing (SA) and Tabu Search (TS), to enhance power system security by optimizing power flow while minimizing fuel costs. Unlike traditional OPF methods, the hybrid approach effectively mitigates line flow limit violations and improves voltage stability under contingency conditions. The key contribution lies in its enhanced convergence efficiency and robustness, making it a promising solution for security-constrained optimal power flow (SCOPF). The findings demonstrate significant improvements in operational security, offering practical applications for modern smart grids facing increased energy demand and reliability concerns. Given the growing complexity of power networks, the proposed approach provides a scalable and adaptive solution, contributing to the development of more secure and resilient power systems in the current energy landscape.

REFERENCES:

[1] J. Yuryevich and K. P. Wong, "Evolutionary Programming Based Optimal Power Flow Algorithm", IEEE Transactions on Power Systems, Vol. 14, No. 4, 1999, pp. 1245-1250.

[2] D. Devaraj and B. Yegnanarayana, "Genetic-Algorithm-Based Optimal Power Flow for Security Enhancement", IEE Proceedings-Generation, Transmission and Distribution, Vol. 152, No. 6, 2005, pp. 899-905.

[3] M.A. Abido, "Optimal Power Flow Using Particle Swarm Optimization, International Journal of Electrical Power & Energy Systems", Vol.24, No. 7, 2002, pp. 563-571.

[4] C.A. Roa-Sepulveda and B.J. Pavez-Lazo, "A Solution to the Optimal Power Flow Using Simulated Annealing", Electrical Power and Energy Systems, Vol.25, No.1,2003, pp.47-57.

[5] T. Sousa, J. Soares, Z. A. Vale, H. Morais and P. Faria, "Simulated Annealing Metaheuristic to Solve the Optimal Power Flow", Proc. of IEEE Power and Energy Society General Meeting 2011, Detroit, MI, USA, 2011, pp. 1-8.

[6] M. A Abido, "Optimal Power Flow Using Tabu Search Algorithm, Electric Power Components Systems", Vol.30, No. 5, 2002, pp. 469-483.

[7] T. Kulworawanichpong and S. Sujitjom, "Optimal Power Flow Using Tabu Search, IEEE Power Engineering Review", Vol.22, 2002, pp. 37-40.

[8] M. R. AlRashidi and M. E El- Hawary, "Hybrid particle swarm optimization approach for solving the discrete OPF problem considering the valve loading effects", IEEE Transactions on Power Systems, Vol. 22, N0.4 ,2007, pp. 2030–2038.

[9] K. Gnanambal and C.K. Babulal, "Maximum Loadability Limit of Power System Using Hybrid Differential Evolution with Particle Swarm Optimization", International Journal of Electrical Power & Energy Systems, Vol.43, 2012, pp. 150-155.

[10] M. J. Morshed and A. Asgharpour, "Hybrid Imperialist Competitive-Sequential Quadratic Programming (HIC- SQP) Algorithm for Solving Economic Load Dispatch with Incorporating Stochastic Wind Power: A Comparative Study on Heuristic Optimization Techniques", International Journal of Energy Conversion and Management, Vol.84, 2014, pp. 30-40.

[11] M. Joorabian and E. Afsan, "Optimal Power Flow Under both Normal and Contingent Operation Conditions Using the Hybrid Fuzzy Particle Swarm Optimization and Nedler-Mead Algorithm (HFPSO-NM)", Applied Soft Computing, Vol.14,2014, pp. 623-633.

[12] A. Rajan and T. Malakar, "Optimal Reactive Power Dispatch Using Hybrid Nelder–Mead Simplex Based Firefly Algorithm", International Journal of Electrical Power & Energy Systems, Vol.66, 2015, pp. 9-24.

[13] A. Panda and M. Tripathy, "Security Constrained Optimal Power Flow Solution of Wind-Thermal Generation System Using

Modified Bacteria Foraging Algorithm", Energy, Vol.93, 2015, pp. 816-827.

[14] Y. Xu, H. Yang, R. Zhang, Z .Y. Dong, M. Lai, and K.P. Wong, "A Contingency Partitioning Approach for Preventive-Corrective Security-Constrained Optimal Power Flow Computation", Electric Power Systems Research, Vol.132, 2016, pp.132-140.

[15] K. Pandiarajan and C.K. Babulal, "Fuzzy Harmony Search Algorithm Based Optimal Power Flow for Power System Security Enhancement, International Journal of Electrical Power & Energy System", Vol.78, 2016, pp.72–79.

[16] K. Teeparthi and D.M. Vinod Kumar, "Multi-Objective Hybrid PSO-APO Algorithm Based Security Constrained Optimal Power Flow with Wind and Thermal Generators, Engineering Science and Technology", an International Journal, Vol.20,2017, pp.411-426.

[17] O. Alsac and B. Stott, "Optimal Load Flow with Steady-State Security", IEEE Transactions on Power Apparatus and Systems, Vol.93, 1974, pp. 745-751.

[18] Samir S and Khaled Z., "Modified Differential Evolution Algorithm for Optimal Power Flow with Non-Smooth Cost Functions, Energy Conversion and Management", Vol. 49, No. 11, 2008, pp. 3036–3042.

[19] Allaoua B and Laoufi A., "Optimal Power Flow Solution Using Ant Manners for Electrical Network, Advances in Electrical and Computer Engineering", Vol. 9, 2009, pp. 34–40.

[20] Ch. Padmanabha Raju, K. Vaisakh and S. Sivanaga Raju, "Power System Security Enhancement and Real Power Loss Reduction by IPM-EPSO Hybrid Method Based Solution of Optimal Power Flow Problem", International Journal of Power System Optimization, Vol.2, No.2, 2010, pp. 115-129.