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POWER SYSTEM SECURITY EVALUATION USING COMPOSITE LOGIC CRITERIA

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ABSTRACT

An important problem in a big integrated power system is an evaluation of the power system security. Machine safety may be categorized based on key roles in control centers, such as the management of the system, the review of contingency, and the assessment of protection. Contingency analysis is the core factor of the threat evaluation. Every contingency cannot trigger the same degree of seriousness in real-time. The concept of severity and performance indexes seems to satisfy this desire to exclude non-violation cases and pick only crucial cases, known as a contingency analysis. Protection improvement includes an optimum flow of power, which is guaranteed by preventative control steps and correcting measures that ensure that the system operates as normal, in the presence of contingencies. Controllable measures to minimize special objective functions including fuel costs, mixed logical parameters, and weighted multi-objective indexes according to operating power system constraints are recommended in the Evolutionary Particular Swarm Optimization Method, which is combined with Interior Point Method. This paper presents IEEE 30 & 39 Bus Security Evaluation simulation findings. We are looking at soft computing strategies to evaluate power system safety.

Keywords: *Power system security, Contingency analysis, Static security assessment, composite logic criteria, IPM-EPSO.*

1. INTRODUCTION

In today's vast integrated networks during emergencies, energy system security evaluation has become a dynamic and challenging issue. The evaluation of safety is a study conducted to ascertain the reasonableness of the power system against unpredicted threats (contingencies) [1–3] and what extent of it. Contingency mitigation is the bottleneck in the safety evaluation. It combines with an optimum power flow called optimal power flow, which is restricted by security. This aims at changing the system by preventive and corrective control measures. Static as well as dynamic safety evaluation can be categorized. The static security assessment is described as the power systems' ability to withstand credible contingencies and to monitor limit breaches following a failure (line outage or generator outage or any fault). It is assumed, however, that the operating point is stable; it cannot capture variations in the operation of the power grid. The Dynamic Security Assessment (DSA) also examines the capacity of an electricity grid, in its transient state, to withstand such contingencies to shift an acceptable steady point [4-7].

The significance of static safety evaluation is a forecast of continuously stable line and bus voltages [8–10]. Contingency mitigation is the bottleneck in the safety evaluation. The contingency ranking and collection can be divided into two sections. A variety of potential incidents will occur in real time. This does not affect the energy system to the same basis and helps differentiate between extreme contingencies and less severe contingencies. The objective of the contingency classification is to assess the rating of all contingencies according to their severity, while the selection of contingency determines the most dangerous contingents throughout the method. The success indicators or testing techniques used were analyzed based on approximation studies [11-14].

Contingency rankings aim to assess how severe all contingencies are while selecting a contingency to classify the most dangerous contingencies in the power structure. The two are checked on an approximation basis by efficiency indexes or by methods of projection [11-14]. A rapid voltage monitoring and rating are carried out using the neural cascading network to determine the contingencies causing voltage issues [15]. The disadvantage of this proposed approach is that it would have increased the number of neural networks. In [16], a rapid emergency rating of the static safety evaluations has been identified to predict the safety level of the device through the RBF network. Two neural networks are being applied in this work, one for the prediction of voltage and one for the calculation of phase angle for both ordinary and contingency scenarios. These estimates are also used for assessing PIs for contingency screening. An ANN pattern recognition has been discussed in [17] for the evaluation of static, transient, and dynamic security.

Previously, a variety of mathematical (Conventional) algorithms have been addressed to resolve optimum power flow (OPF) problems, e. g. the Newton method [18], linear programming, gradient method [19], and mixed-integer linear programming [20-22]. These methods face difficulties in dealing with limitations on inequalities and do not guarantee that the solution is almost ideal [23]. To solve this problem, many non-conventional (heuristic) methods such as GA [24], PSO [25], an algorithm of differential evolution (DEE) [26], evolutionary programming [27], the algorithm of the gravitational quest [28], Firefly Algorithm [29] and Bat Algorithm [30-32] were applied for the resolution of the OPF problem. The improved PSO system is used to reduce overload lines by re-scheduling the units to reduce severity index and fuel costs [33]. To solve the multi-period SCOPF model rather than solve the SCOPF problem with the single interval of time [34], new stochastic research improved artificial bee colony algorithm is proposed.

There is more time taken for estimation is the major disadvantage of complete simulation techniques. A modern composite logic approach is proposed to evaluate static protection to satisfy and overcome this challenge. It presents the IEEE 30 & 39 bus system essential contingency ranking based on the composite logic criterion. Enhanced safety includes an optimum safety-related power flow by EPSO & IPM-EPSO methods, which assures that the device works normally through preventive and correction steps, in order not to cause a breach of contingency. This leads to management measures being implemented through a rescheduling generation.

2. COMPOSITE LOGIC CRITERIA

The Fuzzy set theory was proposed by Prof. L.A. Zadeh in 1965 as a mathematical concept. Fuzzy logic is a logic that uses graded or quantified statements instead of purely true and false statements.

A composite logic criteria method run in parallel is used to achieve the cumulative composite logic criteria table, as seen in Figure 1, for pre/post-contingency operational conditions. The Composite Logic Criteria (CLC) index is designed for determining a cumulative severity index for line loading, voltage profiles, and stability indices.

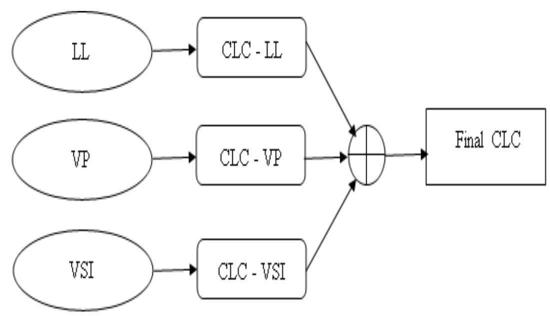

Figure 1: Parallel operated composite logic criteria system

The fuzzy set of linguistic variables allows objects with membership ratings between 0 and 1. Intervals are established based on pre/post contingent amounts for fuzzification of cognitive elements. The input and output membership functions are selected based on the assignment of pre/post-dependent quantities. The pre/post-dependent quantity is first defined in a fuzzy notation before the fuzzy logic rules can be processed. As seen in Table 1, of loading line (LL) is divided into four groups utilizing a fuzzy set of notes. After obtaining the intensity indexes of all the lines, the cumulative index (Total IndexLL) is obtained for a given line output using the following expression.

$$\text{Total Index}_{LL} = \sum w_{LL}\ SI_{LL} \qquad (1)$$

where

w_{LL} = Coefficient of weighting,

SI_{LL} = Index of intensity

The severity index weighting coefficients used are

w_{LL} = 0.25 for LS, 0.50 for US, 0.75 for SA and 1.00 for HS.

The result was that the overall index was predominantly governed by a fourth index (HS). Each bus voltage profile (VP) is split into three categories using fuzzy set notes, as shown in Table 2. When choosing extreme indices for all voltage

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profiles, the Total $Index_{VP}$ of the bus voltage profiles for a specific line outage is obtained by using the following expression.

$$\text{Total Index}_{VP} = \sum w_{VP}\ SI_{VP} \quad (2)$$

The severity index weighting coefficients used are

w_{VP} = 0.30 for US, 0.60 for SA and 1.00 for HS.

As seen in Table 3, every VSI is divided into five groups with fuzzy set comments.

Using this expression, the Total $Index_{VSI}$ of the Bus Voltage Stability Index is obtained after obtaining the severity indices of all the voltage stability indices

$$\text{Total Index}_{VSI} = \sum w_{VSI}\ SI_{VSI} \quad (3)$$

The weighting coefficients used for the severity indices are

w_{VSI} = 0.20 for VLS, 0.40 for LS, 0.60 for US, 0.80 for SA and 1.00 for HS

where

w_{VSI} = Coefficient of weighting,

SI_{VSI} = Pre/post contingent quantity severity index

Table 1: Fuzzy set notations for line loadings.

Percentage Line Loading	0-50%	51-85%	86-100%	Above 100%
Linguistic Variable	Loaded Lightly (LL)	Loaded Usually (LU)	Completely Loaded (CL)	Loaded Over (LO)
Severity Membership Function	Low Severe (LS)	Under Severe (US)	Severe Above (SA)	Higher Severity (HS)

Table 2: Fuzzy set notations for voltage profiles.

Voltage Profile (p.u)	Below 0.9	0.9 to 1.02	Above 1.02
Linguistic Variable	Low Voltage (LV)	Normal Voltage (NV)	Over Voltage (OV)
Severity Membership Function	Under Severe (US)	Severe Above (SA)	Higher Severity (HS)

Table 3: Fuzzy set notations for voltage stability indices.

Voltage Stability Index Value	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1
Linguistic Variable	Very Low Index (VLI)	Low Index (LI)	Medium Index (MI)	High Index (HI)	Very High Index (VHI)
Severity Membership Function	Very Low Severe (VLS)	Low Severe (LS)	Under Severe (US)	Severe Above (SA)	Higher Severity (HS)

3. EVOLUTIONARY PARTICLE SWARM OPTIMIZATION

Miranda et al. [35-36] developed EPSO, combining conventional PSO and evolutionary strategy. It can be regarded either as an evolving PSO weight or as an evolving algorithm with a PSO motion rule. EPSO has already demonstrated its effectiveness, precision, and robustness, which makes it applicable to problems in power systems. EPSO can be viewed as a hybrid process for the development of strategies and optimization of particle swarm methods. The following is the EPSO algorithm. Consider several solutions or particles in a given iteration. The following are the general plans of the EPSO:

- REPLICATION: Replicated R times for each particle
- MUTATION: Strategic parameters of each particle changes
- REPRODUCTION: Each particle mutated produces descendants according to the rule of particulate motion.

- EVALUATION: fitness assessed for each offspring.
- SELECTION: The best particles survive to form a new generation by the stochastic tournament or by other selection processes.

A new particle results a

$$s_i^{new} = s_i + v_i^{new} \quad (4)$$

$$v_i^{k+1} = w_{i0}^* v_i^k + w_{i1}^* \left(pbest_i - s_i^k\right) + w_{i1}^* \left(gbest^* - s_i^k\right) \quad (5)$$

So far, this appears to be the PSO—it retains its inertia, memory and cooperation conditions. However, weights change as specified

$$w_{ik}^* = w_{ik} + \tau . N(0,1) \quad (6)$$

Where, N (0, 1) is the Gaussian distribution random variable, the mean 0 and variance 1. The next equation randomly disturbs the global best (*gbest*)

$$gbest^* = gbest + \tau' . N(0,1) \quad (7)$$

The τ, τ' is parameters for learning. They are also strategic parameters and are therefore subject to mutation.

It is therefore only natural that it should be expected to have favorable convergent qualities when compared with EP or PSO because this system benefits from two "pushes" in the right directions, the Darwinist selection, and the particle movement rule. Moreover, EPSO can also be categorized as an algorithm that can adapt itself, because it relies just like all development strategies on the mutation and selection of strategic parameters.

4. HYBRID IPM-EPSO ALGORITHM

The Interior Point Method (IPM) can look for non-linear and discontinuous function solutions for optimization challenges. However, the slow convergence is often characterized by the almost optimum value and the solution can stay with the local area. The suggested algorithm combines two methods' main advantages accordingly. First of all, IPM is used in the randomly generated initial population to perform global exploitation. This gives evolutionary particle swarm optimization a good starting point (EPSO). The hybrid solution also goes beyond one method, operates only but decreases the total computation time because of its complementary IPM and EPSO properties.

Figure 2 shows the concept of a proposed method based on the two-layer optimization, wherein Layer 1 the initial solutions are randomly generated by the IPM, layer 2 is responsible for optimizing the optimum output variables by the EPSO system.

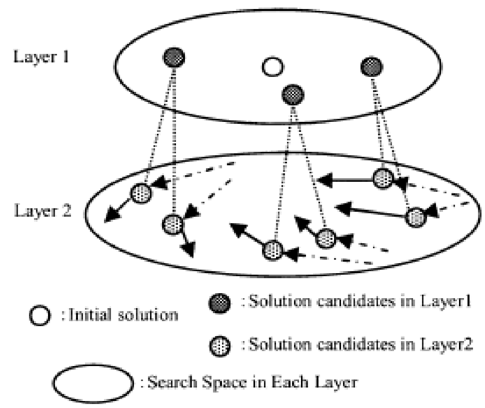

Figure 2: Concept of proposed method

4.1 Objectives

The objectives considered for minimization are as follows.

Objective Function 1: Fuel cost of generating units (f_1)

Objective Function 2: Severity index based on line loadings (f_2)

Objective Function 3: Composite Logic Criteria (CLC) (f_3)

Objective function 4: Weighted sum multi-objective function (f_4)

Where,

$$f_1 = \min\left(\sum_{i=1}^{NG} (a_i P_{Gi}^2 + b_i P_{Gi} + C_i)\right) \quad (8)$$

$$f_2 = \min\left(\sum_{i=1}^{NL} \left(\frac{S_l}{S_l^{\max}}\right)^{2m}\right) \quad (9)$$

$$f_3 = \min(\text{CLC-LL+CLC-VP+CSI-VSI}) \quad (10)$$

m = integer exponent (fixed as 1)

$$f_4 = w_1 f_1 + w_2 f_3 \quad (11)$$

Here $w_1 + w_2 = 1$

The weight multiplying each parameter is adjusted to represent each objective's relative value compared with others. The topic of minimization is subject to limits of equity and inequalities.

4.2 Overall Computational Procedure for Solving the Problem

Implementation steps can be written as follows for the proposed algorithm based on EPSO/IPM-EPSO:

Step 1: Enter the load flow analysis method data
Step 2: Run the power flow in the chosen contingent system (transformer/transfer line outage)
Step 3: Assign a composite logic criteria-based solution to evaluate the magnitude of network contingency.
Stage 4: Repeat steps 2 and 3 for all lines and transformers
Step 5: Choose the most serious network contingencies based on the composite logic criteria based severity index.
Step 6: At generation Gen =0; set the EPSO/IPM-EPSO. Enter simulation parameters to randomly begin k-parameters and save them into the archive, within the respective limits.
Step 7a: Run IPM-based OPF for highly developed individuals with initial k people.
Step 7b: Run power flow under the chosen network contingency for each highly advanced entity in an archive to decide the voltages of the bus, angle, the stability indices of the bus voltage, the reactive power outputs of generators and the line current flows.
Step 8: Assess penalty features
Step 9: Evaluate for each individual objective function value and associated fitness values.
Step 10: Find and store the best xglobal and xlocal.
Step 11: Enhance the Gen = Gen+1 generation counter.
Step 12: To apply the operators of EPSO to create new persons
Step 13: Run power flows to evaluate loading bus voltages, angles, loading bus voltage stability indexes, reactive power output generator and line power flow calculation for each new person in the archive.
Step 14: Assess the role of penalty
Step 15: Assess objective function values for each new person and the associated fitness values.
Step 16: Apply and correct the collection of the EPSO.
Step 17: Update and stock xglobal from the best locally and globally.
Phase 18: Repeat steps 7-17 if one of the stop criteria was not met. The other way is to go 19
Step 19: printing results

5. RESULTS AND DISCUSSIONS

The detailed research on IEEE 30 & 39 bus testing systems for safety assessment is presented in this section. The analysis considered two separate cases. In the initial scenario, for the network contingency ranking, the proposed composite logic requirements were applied. In the second instance, to mitigate overload under the chosen collection of extreme network contingency through the solution of optimal power flow, the composite logic parameters, and EPSO, IPM-EPSO, were applied.

CASE 1: Contingency Ranking Using CLC Approach

In this scenario, the proposed composite logic solution to network contingency ranking was used to identify the harmful contingencies. During the contingency study in IEEE 30 bus system, a large amount of excess on other lines was identified in lines 2-5, 11-13, and 8-11. Similarly, Contingency analysis was conducted on IEEE 39 bus system and critical contingencies are identified in lines 15-16 and 32-33. Figures 3 & 4 assess and show severity indices for line loadings, voltage profiles, and voltage reliability indices for the top 10 network contingencies. Where some CLC-LL, CLC-VP, CLC-VSI index are taken into account, then the rating does not provide an exact contingency magnitude. Figure 3 and Figure 4 shows the efficiency of assessing the magnitude of the network contingency when considering the entire indicator.

For the top ten network contingencies, Table 4 and 5 gives the number of lines and the number of load buses for each difficulty group. For IEEE 30 bus system, the line outage 2-5 is seen to be the most extreme and results in a maximum overall index of severity relative to other lines shown in Figure 3 and Table 4. At the same time From Figure 4 and Table 5 for IEEE 39 bus system, it is found that line outage 15–16 is the most severe one, and results in a maximum total severity index compared to other lines.

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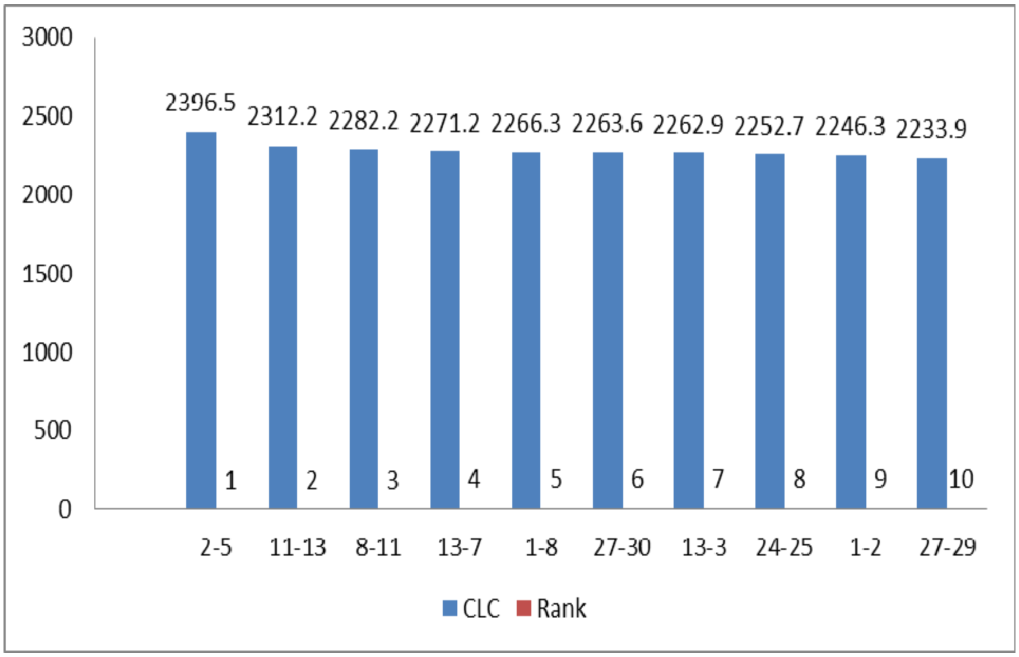

Figure 3: Overall CLC and ranking for IEEE-30 bus system

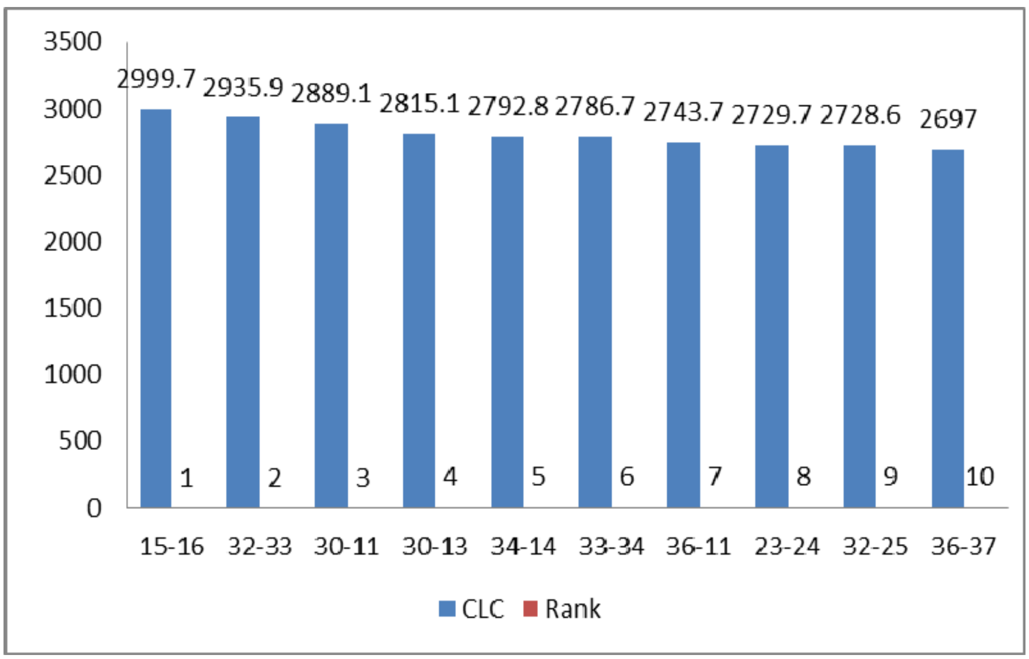

Figure 4: Overall CLC and ranking for IEEE-39 bus system

Table 4: Number of lines/buses under different severity category before optimization

Line outage	Line Loadings				Bus Voltage Profiles			Bus Voltage Stability Indices					RANK
	LS	US	SA	HS	US	SA	HS	VLS	LS	US	SA	HS	
2-5	28	8	2	2	0	8	16	24	0	0	0	0	1
11-13	31	7	0	2	0	8	16	24	0	0	0	0	2
8-11	33	4	1	2	0	8	16	24	0	0	0	0	3
13-7	34	5	1	0	0	6	18	24	0	0	0	0	4

1-8	33	4	1	2	0	8	16	24	0	0	0	0	5
27-30	32	6	2	0	0	7	17	23	1	0	0	0	6
13-3	33	6	1	0	0	7	17	24	0	0	0	0	7
24-25	34	5	1	0	0	6	18	24	0	0	0	0	8
1-2	33	4	0	3	0	9	15	24	0	0	0	0	9
27-29	33	5	2	0	0	7	17	24	0	0	0	0	10

Table 5: Number of Lines/buses under different severity categories before optimization for IEEE-39 bus system

Line outage	Line Loading				Voltage Profile			Voltage Stability Indices					Rank
	LS	US	SA	HS	US	SA	HS	VLS	LS	US	SA	HS	
15-16	17	24	2	2	0	15	14	24	5	0	0	0	1
32-33	16	22	3	4	0	20	9	17	12	0	0	0	2
30-11	22	18	1	4	0	17	12	26	3	0	0	0	3
30-13	21	19	2	3	0	18	11	24	5	0	0	0	4
34-14	19	24	0	2	0	15	14	28	1	0	0	0	5
33-34	21	24	0	0	0	13	16	26	3	0	0	0	6
36-11	21	21	0	3	0	18	11	26	3	0	0	0	7
23-24	21	20	1	3	0	19	10	23	6	0	0	0	8
32-25	19	22	1	3	0	19	10	28	1	0	0	0	9
36-37	21	22	1	1	0	17	12	26	3	0	0	0	10

CASE 2: OPF for overload alleviation/security evaluation

To test the ability of the proposed IPM-EPSO hybrid algorithm for solving optimal power flow problems to alleviate overloads, it was applied under the selected three most severe network contingencies for the IEEE-30 bus system and two most severe network contingencies for the IEEE-39 bus system. Four objective functions are considered for the minimization using the proposed IPM-EPSO algorithm namely cost of generation, line flow based severity index, composite logic criteria based index, and weighted sum multi-objective function which is formed with the first and third objective functions. Table 6 presents the various performance parameters under the rank 1, 2, and 3 network contingencies with the four objective functions. Table 8 presents the number of lines/buses under different severity categories for the three network contingencies for all the four objective functions for the IEEE-30 bus system. Similarly, Tables 7 & 9 presents the overall severity indices and the number of lines/buses under different severity categories for the two network contingencies for all the four objective functions for the IEEE-39 bus system. From Tables 6, 7, 8, and 9, it is observed that the OPF solution with cost objective function gives the reduced cost of generation but it has unattractive voltage profiles and over loadings under contingency conditions. During minimization of the objective function-2, the cost of generation has been increased considerably when compared with objective-1, but it was so effective in alleviating the line overloads by reducing the concerned severity index.

During minimization of the third objective function i.e. composite logic criteria based severity index, it has been observed that the security has been improved in terms of improvement in the voltage profile, voltage stability index, and decrement in the line loadings is observed using decrement in the CLC based severity index.

From Tables 6 and 7, it can also be observed that, during minimization of the weighted multi-objective function, in solving the optimal power flow problem, the IPM-EPSO and EPSO methods can alleviate the overloads effectively compared to objective function-1. This shows the effectiveness of the proposed CLC objective function in achieving a minimum of the specified objective function and security enhancement.

Table 6: Overall severity indices and ranking for IEEE-30 bus system.

Line outage	Objective function	OPF Technique	CLC-LL	CLC-VP	CLC-VSI	CLC
2-5	Objective Function 1	EPSO	541	952	96	1589
		IPM-EPSO	501	912	96	1509
	Objective Function 2	EPSO	384	968	96	1448
		IPM-EPSO	386	875	96	1357
	Objective Function 3	EPSO	360	864	96	1320
		IPM-EPSO	360	864	96	1320
	Objective Function 4	EPSO	424	864	96	1384
		IPM-EPSO	442	846	96	1384
11-13	Objective Function 1	EPSO	465	1079	96	1640
		IPM-EPSO	465	991	96	1552
	Objective Function 2	EPSO	314	916	96	1326
		IPM-EPSO	314	914	96	1324
	Objective Function 3	EPSO	289	864	96	1249
		IPM-EPSO	289	864	96	1249
	Objective Function 4	EPSO	327	864	96	1287
		IPM-EPSO	326	864	96	1286
8-11	Objective Function 1	EPSO	420	919	96	1435
		IPM-EPSO	410	919	96	1425
	Objective Function 2	EPSO	335	928	96	1359
		IPM-EPSO	338	928	96	1362
	Objective Function 3	EPSO	307	919	96	1322
		IPM-EPSO	307	919	96	1322
	Objective Function 4	EPSO	359	928	96	1383
		IPM-EPSO	358	928	96	1382

Table 7: Overall severity indices and ranking for IEEE-39 bus system.

Line outage	Objective function	OPF Technique	CLC-LL	CLC-VP	CLC-VSI	CLC
15-16	Objective Function 1	EPSO	860	1420	140	2420
		IPM-EPSO	860	1150	150	2160
	Objective Function 2	EPSO	778	2492	133	3403
		IPM-EPSO	682	2389	134	3205
	Objective Function 3	EPSO	660	1050	140	1850
		IPM-EPSO	610	1050	140	1800
	Objective Function 4	EPSO	790	1060	140	1990
		IPM-EPSO	700	1070	140	1910
32-33	Objective Function 1	EPSO	990	1250	190	2430
		IPM-EPSO	990	1140	210	2340
	Objective Function 2	EPSO	831	2106	169	3106
		IPM-EPSO	809	2252	181	3242
	Objective Function 3	EPSO	750	1050	210	2010
		IPM-EPSO	710	1040	210	1960
	Objective Function 4	EPSO	820	1040	220	2080
		IPM-EPSO	760	1050	220	2030

Table 8: Number of Lines/buses under different severity categories for IEEE-30 bus system

Line outage	Objective Function	Method	Line Loadings				Bus Voltage Profiles			Bus Voltage Stability Indices				
			LS	US	SA	HS	US	SA	HS	VLS	LS	US	SA	HS
2-5	Before Optimization		28	8	2	2	0	8	16	24	0	0	0	0
	Objective Function1	EPSO	29	9	0	2	0	22	2	24	0	0	0	0
		IPM-EPSO	30	8	1	1	0	23	1	24	0	0	0	0
	Objective Function 2	EPSO	32	8	0	0	0	22	2	24	0	0	0	0
		IPM-EPSO	32	8	0	0	0	24	0	24	0	0	0	0
	Objective Function 3	EPSO	34	6	0	0	0	24	0	24	0	0	0	0
		IPM-EPSO	34	6	0	0	0	24	0	24	0	0	0	0
	Objective Function 4	EPSO	32	7	1	0	0	24	0	24	0	0	0	0
		IPM-EPSO	32	6	2	0	1	23	0	24	0	0	0	0
11-13	Before Optimization		31	7	0	2	0	8	16	24	0	0	0	0
	Objective Function1	EPSO	32	6	2	0	0	20	4	24	0	0	0	0
		IPM-EPSO	32	6	2	0	0	22	2	24	0	0	0	0
	Objective Function 2	EPSO	36	4	0	0	0	23	1	24	0	0	0	0
		IPM-EPSO	36	4	0	0	0	23	1	24	0	0	0	0
	Objective Function 3	EPSO	38	2	0	0	0	24	0	24	0	0	0	0
		IPM-EPSO	38	2	0	0	0	24	0	24	0	0	0	0
	Objective Function 4	EPSO	36	4	0	0	0	24	0	24	0	0	0	0
		IPM-EPSO	36	4	0	0	0	24	0	24	0	0	0	0
8-11	Before Optimization		33	4	1	2	0	8	16	24	0	0	0	0
	Objective Function1	EPSO	33	6	0	1	0	23	1	24	0	0	0	0
		IPM-EPSO	34	5	0	1	0	23	1	24	0	0	0	0
	Objective Function 2	EPSO	35	5	0	0	0	23	1	24	0	0	0	0
		IPM-EPSO	35	5	0	0	0	23	1	24	0	0	0	0
	Objective Function 3	IPM-EPSO	37	3	0	0	0	23	1	24	0	0	0	0
		IPM-EPSO	37	3	0	0	0	23	1	24	0	0	0	0
	Objective Function 4	EPSO	36	3	1	0	0	23	1	24	0	0	0	0
		IPM-EPSO	36	3	1	0	0	23	1	24	0	0	0	0

Table 9: Number of Lines/buses under different severity categories for IEEE-39 bus system.

Contingency	Objective Function	Method	Line Loadings				Bus Voltage Profiles			Bus Voltage Stability Indices				
			LS	US	SA	HS	US	SA	HS	VLS	LS	US	SA	HS
15-16	Before Optimization		17	24	2	2	0	15	14	24	5	0	0	0
	Objective Function1	EPSO	17	25	2	1	0	22	7	26	3	0	0	0
		IPM -EPSO	18	24	2	1	0	27	2	25	4	0	0	0
	Objective Function 2	EPSO	23	17	5	0	0	4	25	27	2	0	0	0
		IPM -EPSO	25	18	2	0	0	5	24	27	2	0	0	0
	Objective Function 3	EPSO	28	15	2	0	0	29	0	26	3	0	0	0
		IPM -EPSO	29	15	1	0	0	29	0	26	3	0	0	0
	Objective Function 4	EPSO	22	20	3	0	0	29	0	26	3	0	0	0
		IPM -EPSO	24	19	2	0	0	29	0	26	3	0	0	0
32-33	Before Optimization		16	22	3	4	0	20	9	17	12	0	0	0
	Objective Function1	EPSO	20	21	1	3	0	25	4	20	9	0	0	0
		IPM -EPSO	18	24	0	3	0	27	2	18	11	0	0	0
	Objective Function 2	EPSO	18	25	2	0	0	9	20	23	6	0	0	0
		IPM -EPSO	21	21	3	0	0	7	22	21	8	0	0	0
	Objective Function 3	EPSO	25	16	4	0	0	29	0	18	11	0	0	0
		IPM -EPSO	24	19	2	0	0	29	0	18	11	0	0	0
	Objective Function 4	EPSO	21	20	4	0	0	29	0	18	11	0	0	0
		IPM -EPSO	21	22	2	0	0	29	0	18	11	0	0	0

6. CONCLUSIONS

Sustained economic growth would lead to a persistent increase in regional or comprehensive electricity demand. Also, unrestricted access to the transmission networks will result in massive variations in electricity flows across lines and voltage infringements of buses in a deregulated electric power grid due to numerous reasons such as increased diverse power transfers, unforeseen power exchanges, and unintended outages. In this situation, there could be significant challenges to the stability of the power grid. A

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detailed overview of static safety evaluation and discussion of security improvement problems are included in this article. The Soft Computing Technology built on IPM-EPSO is presented to test the safety of static systems. Finally, we discuss the meta-heuristic approaches to assess the safety of the machine. It identifies the key obstacles in broadening the reach of the security issue. For researchers and academics, the general findings reported in this paper would be better and more helpful.

REFERENCES:

[1] Teeparthi, K., Kumar, D.M.V. "An Improved Artificial Physics Optimization Algorithm Approach for Static Power System Security Analysis". *Journal of The Institution of Engineers (India): Series B*, Volume 101, 2020, pp. 347–359. https://doi.org/10.1007/s40031-020-00457-6

[2] Yahui Li 1, Yang Li 1and Yuanyuan Sun, "Online Static Security Assessment of Power Systems Based on Lasso Algorithm" *Applied Sciences*, Volume 8, 2018, pp.1442. doi:10.3390/app8091442

[3] Pudi Sekhar, Sanjeeb Mohanty, "An online power system static security assessment module using multi-layer perceptron and radial basis function network", *International Journal of Electrical Power & Energy Systems*, Volume 76, 2016, pp. 165-173.

[4] N. A. E. R. Council, "Reliability Concepts" in *Bulk Power Electric Systems* (1985)

[5] K. Morison, L. Wang, P. Kundur, Power system security assessment. *IEEE Power Energy Mag.* Volume 2, 2004, pp. 30–39.

[6] A.J. Wood, B.F. Wollenberg, "Power Generation Operation and Control", 2nd edn. Wiley India Private Limited, New Delhi, 2006.

[7] A. Zhukov, N. Tomin, V. Kurbatsky, D. Sidorov, D. Panasetsky, A. Foley, "Ensemble methods of classification for power systems security assessment", *Applied Computing and Informatics*, Volume 15, Issue 1, 2019, pp. 45-53.

[8] R. P. Schulz and W. W. Price, "Classification and Identification of Power System Emergencies," *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-103, no. 12, 1984, pp. 3470-3479. doi: 10.1109/TPAS.1984.318350

[9] EPRI Rep. EPRI EL-5290, "Composite-System Reliability Evaluation: Phase I—Scoping Study"

[10] Kebande, V.R., Karie, N.M. & Ikuesan, R.A. "Real-time monitoring as a supplementary security component of vigilantism in modern network environments". *International Journal of Information Technology*, volume 13, No 1, 2021, pp. 5–17. https://doi.org/10.1007/s41870-020-00585-8

[11] H. Glavitsch, "Switching as means of control in the power system". *Int. J. Electr. Power Energy Syst.* volume 7, No. 2, 1985, pp. 92–100.

[12] M. Shahidehpour, W.F. Tinney, Y. Fu, "Impact of security on power systems operation". *Proc. IEEE* volume 93, No. 11, 2005, pp. 2013–2025.

[13] Abdullah M. Al-Shaalan, "Contingency selection and ranking for composite power system reliability evaluation", *Journal of King Saud University – Engineering Sciences*, volume 32, 2020, pp. 141–147

[14] Prasad, Manorath & Puhan, Subhranshu & Patra, Subham. "Contingency Selection in the Context of Voltage Security Margin Determination". *ICICCT 2019 – System Reliability, Quality Control, Safety, Maintenance and Management Springer*, pp. 744–752, 2020, doi: 10.1007/978-981-13-8461-5_85.

[15] Wu, L., Venayagamoorthy, G.K., Gao, J. "Online Steady-State Security Awareness Using Cellular Computation Networks and Fuzzy Techniques". *Energies*, Volume 14, 2021, pp. 148. https://doi.org/10.3390/en14010148.

[16] Jorge W. Gonzalez, Idi A. Isaac, Gabriel J. Lopez, Hugo A. Cardona, Gabriel J. Salazar, John M. Rincon, "Radial basis function for fast voltage stability assessment using Phasor Measurement Units", *Heliyon*, Volume 5, Issue 11, 2019, pp. e02704. https://doi.org/10.1016/j.heliyon.2019.e02704.

[17] S. R, R. S. Kumar and A. T. Mathew, "Online Static Security Assessment Module Using Artificial Neural Networks," *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 4328-4335, Nov. 2013, doi: 10.1109/TPWRS.2013.2267557.

[18] A.J. Santos, "Optimal-power-flow solution by Newton's method applied to an augmented Lagrangian function". *IEE Proc.*

Gener.Transm. Distrib. vol.142, no.1, pp. 33 1995.

[19] M.K. Mangoli, K.Y. Lee, Y. Moon Park, “Optimal real and reactive power control using linear programming”, *Electr. Power Syst. Res.* vol. 26, , no.1, 1993, pp. 1–10.

[20] D.Harini, M.Ramesh Babu, C.Venkatesh Kumar, “LP based solution for Security Constrained Optimal Power Flow including Power Routers”, *WSEAS Transactions On Power Systems*, Volume 15, 2020.

[21] Hang Li , Zhe Zhang, Xianggen Yin and Buhan Zhang, “Preventive Security-Constrained Optimal Power Flow with Probabilistic Guarantees”, *Energies*, Volume 13, pp. 2344, 2020 doi:10.3390/en13092344

[22] T. L. Duong, T. T. Nguyen, “Application of Sunflower Optimization Algorithm for Solving the Security Constrained Optimal Power Flow Problem”, *Engineering, Technology and Applied Science Research*, Volume 10, Issue: 3, 2020, pp. 5700-5705.

[23] M. Niu, C. Wan, Z. Xu, A review on applications of heuristic optimization algorithms for optimal power flow in modern power systems. *J. Mod. Power Syst. Clean Energy* Volume 2, No.4, 2014, pp.289–297.

[24] R.N. Banu, D. Devaraj, Multi-objective GA with fuzzy decision making for security enhancement in power system. *Appl. Soft Comput. J.* Volume 12, No. 9, 2012, pp.2756–2764.

[25] M.R. AlRashidi, M.E. El-Hawary, “Hybrid particle swarm optimization approach for solving the discrete OPF problem considering the valve loading effects”. *IEEE Trans. Power Syst.* Volume 22, no. 4, 2007, pp. 2030–2038.

[26] M. Varadarajan, K.S. Sworup, “Solving multi-objective optimal power flow Using differential evolution”. *IET Gener. Transm. Distrib.* Volume 2, no. 5, 2008, pp. 720–730.

[27] H.A. Hejazi, H.R. Mohabati, S.H. Hosseinian, M. Abedi, “Differential evolution algorithm for security-constrained energy and reserve optimization considering credible contingencies”, *IEEE Trans. Power Syst.* Volume 26, no. 3, 2011, pp.1145–1155.

[28] Yasir Muhammad, Rahimdad Khan, Muhammad Asif Zahoor Raja, Farman Ullah, Naveed Ishtiaq Chaudhary, Yigang He, “Solution of optimal reactive power dispatch with FACTS devices: A survey”, *Energy Reports*, Volume 6, 2020, pp. 2211-2229.

[29] Abdulkarim Saleh Masoud Ali A, Rozmie R. Othman, Ym Yacob, “Application of Adaptive Elitism Operator In Firefly Algorithm For Optimization of Local and Global Search” *Journal of Theoretical and Applied Information Technology*, Vol.99. No 3, 2021.

[30] B.V. Rao, G.V.N. Kumar, “Electrical power and energy systems optimal power flow by BAT search algorithm for generation reallocation with unified power flow controller”. *Int. J. Electr. Power Energy Syst*. Volume 68, 2015, pp. 81–88.

[31] Z. Ye, M. Wang, W. Liu, S. Chen, “Fuzzy entropy based optimal thresholding using bat algorithm”, *Appl. Soft Comput. J.* Volume 31, 2015, pp. 381–395.

[32] S. Biswal, A.K. Barisal, A. Behera, T. Prakash, “Optimal power dispatch using BAT algorithm”, in 2013 *International Conference on Energy Efficient Technologies for Sustainability*, pp. 1018–1023, 2013.

[33] Rudi Kurnianto, Hardiansyah, “A Novel Bat Algorithm For Dynamic Economic Power Dispatch With Prohibited Operating Zones” *Journal of Theoretical and Applied Information Technology*, Vol.99. No 1, 2021.

[34] S. Armaghani, N. Amjady, O. Abedinia, “Security constrained multi-period optimal power flow by a new enhanced artificial bee colony”, *Appl. Soft Comput. J.* Volume 37, 2015, pp. 382–395.

[35] V. Miranda and N. Fonseca, "EPSO - best-of-two-worlds meta-heuristic applied to power system problems," *Proceedings of the 2002 Congress on Evolutionary Computation. CEC'02 (Cat. No.02TH8600)*, Honolulu, HI, USA, 2002, pp. 1080-1085 vol.2, doi: 10.1109/CEC.2002.1004393.

[36] V. Miranda and R. Alves, "Differential Evolutionary Particle Swarm Optimization (DEEPSO): A Successful Hybrid," 2013 *BRICS Congress on Computational Intelligence and 11th Brazilian Congress on Computational Intelligence*, Ipojuca, Brazil, 2013, pp. 368-374, doi: 10.1109/BRICS-CCI-CBIC.2013.68