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Hybrid Evolutionary Algorithm Using Optimal Placement of FACTS Devices for Total Transfer Capability

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ABSTRACT

The paper discusses about a hybrid model with an evolutionary algorithm (HEA) for identifying the multi-type flexible AC transmission systems (FACTS) procedures to improve the total transfer capability (TTC). To reduce the loss of power this transferences among various control regions. FACTS devices with Multi objective optimal power flow (OPF) which include TTC to determine a reasonable value without violating system limitations. The results are simulated for FACTS devices with the HEA algorithm which emerges TTC value using an efficient methods using conventional transmission system. The simulation results are obtained by MATLAB/SIMULINK environment.

Introduction

In recent power systems, the applications concerned with power transmission techniques are developed repetitively. Flexible AC transmission systems (FACTS), have been used for controlling the flow of power, enhance stability of transmission, and increase the safety in power transmission system [1]. Additionally, these devices could be maximized power transfer capability & minimized power loss of the transmission systems, which lead for the effective applications compared to the conventional power system. In physical transmission, Available transfer capability (ATC) is used for transferring the capacity in a transmission network. This needs to be measured for every control region which is given in societal problems for enhancing the open acceptance in a power system.

ATC is known as the total transfer capability (TTC) which reduces the transmission reliability margin (TRM), capacity benefit margin (CBM) and the conventional transmission commitments (CTC). The TTC is an important part at ATC calculation. TTC is called the number electrical power which could reassign connected transmission network in a dependable. Huge categories of techniques, like continuation power flow (CPF) [4], linear ATC (LATC) [3], and repetitive power flow (RPF) [5] strategies are introduced to manipulate TTC. Moreover, optimal power flow (OPF) techniques that are developed using several optimizing strategies [6, 7], are introduced for TTC controls several degrees. The technique which needs to find the operations to identify correct solution. Therefore, OPF is a nonlinear function & non-convex optimizing method which results in many solutions that exist the special function in power networks with FACTS devices [8]. The device factors have extra control enables which could not be solved using existing OPF methods due to the factors will alter the impedance. However, existing optimizing techniques are used for local optimal solutions. Recently, the power transfer capability improvement [10] & power loss minimization technique by multi-type FACTS devices. Due to these improve competition, minimize operating costs, and effectively apply the conventional power transmission systems. In addition to the advantages the compatibility of the system how they are controlled with other systems. Therefore, the techniques lead to the correct solution due to the loading conditions. GA is searching the exact location of TCSC and CPF is involved to examine the FACTS devices relevant to thermal limits and voltage limits.

Problem Statement

The devices includes TTC, loss of power in the transmission system and along with Multi-objective OPF FACTS devices are designed to find TTC value which will be moved through a range of generator set for connecting loads. And it has various limits such as reactive power voltage limits, generation limits, thermal limits, FACTS operation limits and steady state stability limits.

FACTS devices are categorized into 4 parts as follows:

1. TCSC
2. Unified power flow controller (UPFC)
3. Thyristor-controlled phase shifter (TCPS)
4. SVC.

Maximize

$$T = \sum_{i=1}^{ND\_SNK} P_{Di} - \sum_{i=1}^{N} (P_{Gi} - P_{Di}) - PF \quad (1)$$

Subject to

$$P_{Gi} - P_{Di} + \sum_{k=1}^{m(i)} P_{Pi}(\alpha_{Pk}) + \sum_{k=1}^{n(i)} P_{Ui}(V_{Uk}, \alpha_{Uk}) \quad (2)$$

$$-\sum_{j=1}^{N} V_i V_j Y_{ij}(X_s) cos\big(\theta_{ij}(X_s) - \delta_i + \delta_j\big) = 0$$

Where

T objective function

PF penalty function

$P^{min}{}_{Gi}$, $P^{max}{}_{Gi}$ real power generation in lower and upper limits at bus i

Q^{min} Gi , P^{max} Gi reactive power generation in lower and upper limits at bus i

$V^{min}{}_{i}$, $V^{max}{}_{i}$ voltage magnitude in lower and upper limits of bus i

$S^{max}{}_{Li}$ i th line or transformer loading limit

$I^{crit}{}_{ij}$ critical angle difference between bus i–j

$X^{min}{}_{Si}$, $X^{max}{}_{Si}$ lower and upper limits of TCSC at line i

$\alpha^{max}{}_{Pi}$, $\alpha^{max}{}_{Pi}$ TCPS lower and upper limits in line i

$V^{min}{}_{Ui}$, $V^{max}{}_{Ui}$ UPFC of lower and upper limits at line i

$\alpha^{min}{}_{Ui}$, $\alpha^{max}{}_{Ui}$ UPFC lower and upper limits at line i

$Q^{min}{}_{Vi}$, $Q^{max}{}_{Vi}$ reactive power injected in SVC at bus i

N, NL amount buses and branches

NG, ND amount load buses

NG_SCE amount of source area

ND_SNK amount of load buses in a sink area

$P^{min}{}_{Gi} \leq P_{Gi} \leq P^{max}{}_{Gi} \quad \forall i \in NG$

$Q^{min}{}_{Gi} \leq Q_{Gi} \leq Q^{max}{}_{Gi} \quad \forall i \in NG$

$V^{min}{}_{i} \leq V_{i} \leq V^{max}{}_{i} \quad \forall i \in N$

$|S_{Li}| \leq S^{max}{}_{Li} \; \forall i \in NL$

$VCPI_i \leq 1 \; \forall i \in N$

$|\delta_{IJ}| \leq \delta^{crit}{}_{ij} \; \forall i \in NL$

$X_{Si}^{min} \leq X_{Si} \leq X_{Si}^{max} \; \forall i \in N$

$\alpha_{Pi}^{min} \leq \alpha_{Pi} \leq \alpha_{Si}^{max}$

$V_{Ui}^{min} \leq V_{Ui} \leq V_{Ui}^{max}$

$\alpha_{Ui}^{min} \leq \alpha_{Ui} \leq \alpha_{Ui}^{max}$

$Q^{min}{}_{Vi} \leq Q_{Vi} \leq Q^{max}{}_{Vi} \quad \forall i \in NG$

Variable series reactance model is subdivided into TCPS, UPFC, and SVC by power model of injected described in Appendix A [19].

In order to enhance EC methods, Hybrid Evolutionary Algorithm (HEA) is introduced along with TS, EP, and SA strategies. Advantages of the HEA algorithm are stated as follows:

Multiple populations along with modification operatives are developed for improving search and increase population update, providing greater caliber of provisions when compared to conventional searching methods.

The procedure is completed for transform and fuse the information contains sub-data assembly brought about by consistency of people in a solitary populace will be eased.

Choice of probabilistic changing method dependent on annealing schedule of SA and TS is given to remove need of operating functions & to get local optimal explanations.

The procedure will certainly simplify similar execution of parallel computers for minimizing the lapsed time foregoing caliber of results.

Four categories in FACTS devices of reasonable every type, that allocates the input information. Position of the system is considered as 3 boundaries: nCF k, 'k' location, and 'k' parameter are considered as load (21).

FACTs devices category is l € {1, 2, 3, 4} involving placement of TCSC, TCPS, UPFC, and SVC, separately, the quantity of FACTs device category l, nCF l 2 f0; 1g. Obviously, none of the FACTs device category l is if nCF l D O or just a single FACTs devices category l if nCF k D l. Along these lines, plenty of FACTs parts, areas, & boundaries of every class FACTs devices at the same time are used with the HEA calculation. All boundaries in FACTs device category k is legitimate just if nCF l D l.

This system is shown in Figure. It is divided as three regions, each has 2 generators. Updated system datasets are specified in [25]. A bilateral transaction has double transactions including from 1 bus to 21 bus & a multilateral transaction starting at region 1 and 2 with the following objectives:

Increase TTC, decrease power loss, increase TTC and low loss

Through 1 bus to 21 by not considering FACTs devices Table 1, in bilateral transaction the load values is 17.50 MW in bus-21. To increase TTC by the proposed strategy, TTC value is taken as 40.447 MW by not altering limits, are 0.84%, 1.29%, 0.58%, and 0.31% through TS, EP, IEP and TS/SA respectively. For minimizing the power loss the current productions and load, bus voltages in generators are improved by adapting methods like TTC, HEA, and power losses is 2.045 and 17.50 Mega Watt, as expected. TTC increase and diminish loss by HEA, TTC is 40.449 MW, that are greater than through EP-0.85%, TS-0.55%, TS/SA-0.38%,

Mediterranean Journal of Basic and Applied Sciences (MJBAS)
Volume 4, Issue 2, Pages 83-92, April-June 2020

and IEP-0.58%. The proposed devices are used to concurrently increase TTC and reduce the loss.

TTC has the value of 154.061Mega Watt by not considering the limits that can be maximized at 280.88% when comparatively with FACTS devices. Moreover, TTC is from EP-22.25%, TS-21.54%, TS/SA-20.91%, and IEP-15.04% methods. To TTC increase or lossless, generally these are developed for improving the TTC and to eliminate power comparatively OPF when not considering the FACTs devices. In Parallel, improve the TTC and decrease the power by HEA technique, TTC is 125.930 Mega Watt, that are more from EP0.21%, TS-0.12%, TS/SA-0.10%, and IEP-0.17% methods. In HEA algorithm also use a source region, growth of output power, and novel improvement in production bus voltages.

In parallel HEA placed every category of FACTs devices are improving TTC and minimizing loss. TTC has 191.379 Mega Watt, which increases 51.97% comparatively than not considering FACTS devices. Additionally, the TTC value is, more EP-40.68%, TS-20.60%, TS/SA-18.40%, and IEP-15.61% methods.

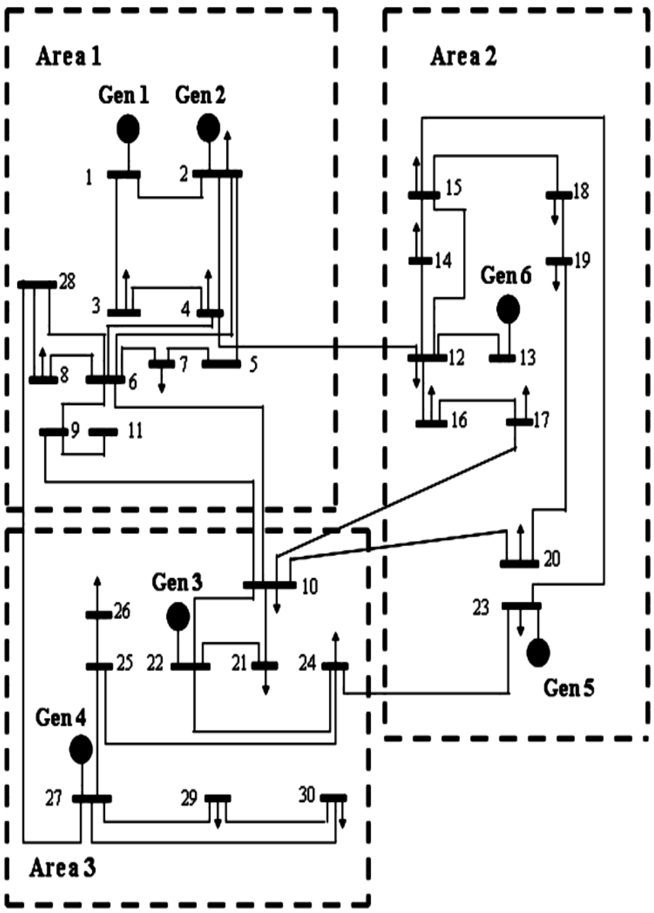

Figure.1 Modified IEEE-30 bus

CPU execution period is the over-all computation time for HEA algorithm beginning to final includes the NR power flow is shown in Figure 4. Using HEA method, results are obtained on the optimized values through various methods due to the selection mechanism of HEA algorithm with an updating approach depends on SA and TS algorithms to reduce the operational set-up corrected values. Hence, the variations of HEA is best solution as small as demonstrated in solutions, which leads for higher stability of HEA method.

The Modified IEEE 118-Bus System

It has 54 numbers of bus generators and 186 branches. It is divided as nine regions, as stated in Figure 5. Thermal limits are specified in [25] and [26], correspondingly. The dataset is improved as follows. Power

Mediterranean Journal of Basic and Applied Sciences (MJBAS)
Volume 4, Issue 2, Pages 83-92, April-June 2020

production has the upper limit in 69 bus is 1,000 Mega Watt. Power production for reactive is upper limits starting from bus 34, 70, and ends in 103 are 80 MVAr. Power production minimum limit is bus 19, 32, 34, 102, and 105 is 22 MVAr. The Thermal limit at line 65–66 is 300 VA.

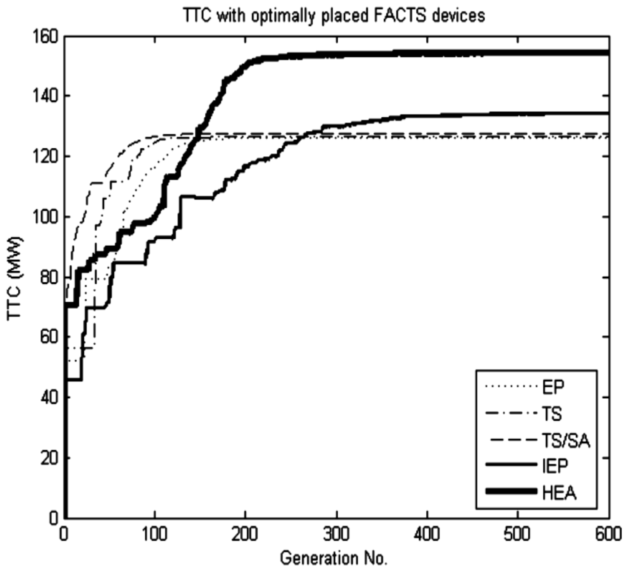

Figure.2 Characteristics of solutions

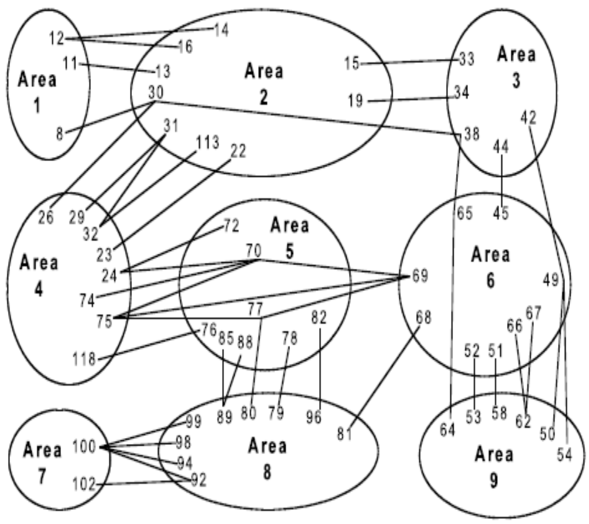

Figure.3 Control areas of the modified IEEE 118-bus system

The ML from region 6 to 3 with contingency constraints is considered. Output of the largest generators for each region and the output are included in the contingency list. Load in region 6 is 406.00 MegaWatt and the system real-power loss is 132.863 MegaWatt. TTC when not considering FACTS devices using HEA method is 710.57 MegaWatt. To find the pre-specified contingency controls are as shown in Table 5, TTC value using HEA algorithm is 461.03 MegaWatt without using network components, which is, from EP-4.89%, TS-5.25%, TS/SA-0.91%, and IEP-0.57%. Additionally, TTC value is minimized by 35.12% comparatively greater by not considering contingency components. Factor has the connected line from 42–49 among two regions are output. It is explained that rejecting the impact of given constraints on TTC is found insecure system operation. In parallel, to improve the TTC and lossless system in HEA has optimally placed every category of FACTS devices. TTC value FACTs devices is 725.17 MW, which is maximized by 2.05% compared to that without FACTs devices.

TTC value using HEA is 513.6 MegaWatt that increases 11.41% comparatively not considering FACTS devices. The interconnected line is 38–65 output among these regions. However, the TTC value is more than from EP-6.77%, TS-7.93%, TS/SA-5.26%, and

Mediterranean Journal of Basic and Applied Sciences (MJBAS)
Volume 4, Issue 2, Pages 83-92, April-June 2020

IEP-4.08%. Table 4 states the corrected placement of multi-type FACTS devices for the TTC values. Simulations are indicated in Table 4 that of EP, TS/SA, and TS, is low efficient than population search of HEA and IEP techniques. Since, the HEA calculation needs greater operation period, for scheduling horizon, the calibre of solutions is high significant.

Table 1: Simulation Results (The Modified IEEE 30-Bus System)

Without FACTS devices						
Maximize TTC			**Minimize loss**		**min. loss**	
Method	TTC	Loss	TTC	Loss	TTC	Loss
EP	124.994	6.421	56.200	2.029	125.663	6.035
TS	125.553	6.140	56.200	2.029	125.781	5.916
TS/SA	125.808	6.287	56.200	2.029	125.806	5.793
IEP	125.451	6.248	56.200	2.029	125.716	5.967
HEA	125.629	6.043	56.200	2.029	125.930	5.738

Conclusion

In this paper, the HEA algorithm is designed to find the optimal placement of FACTs device in multi-type by paralleled increasing TTC value and decreasing the power loss in power transactions among different control regions. The results are obtained for the placement OPF FACTs devices through HEA algorithm. This will increase the TTC value based on the normal and contingency conditions in the proposed system.

With FACTS devices						
	Maximize TTC		**Minimize loss**		**min. loss**	
Method	TTC	Loss	TTC	Loss	TTC	Loss
EP	133.694	6.001	56.200	1.144	136.040	3.980
TS	157.054	6.438	56.200	1.105	157.389	6.449
TS/SA	158.482	6.465	56.200	1.101	161.642	6.971
IEP	158.904	7.057	56.200	0.998	165.545	6.351
HEA	185.095	7.426	56.200	0.968	191.379	6.474

Table 2

Simulation results of multilateral transaction from area based on area 1 to 2 on the modified IEEE 30-bus system

Without FACTS devices						
	Maximize TTC		Minimize loss		Max. TTC &min loss	
Method	TTC	Loss	TTC	Loss	TTC	Loss
EP	39.902	4.584	17.500	2.045	40.111	4.612
TS	40.101	4.624	17.500	2.045	40.295	4.686
TS/SA	40.312	4.775	17.500	2.045	40.293	4.684
IEP	40.203	4.645	17.500	2.045	40.216	4.657
HEA	40.437	4.734	17.500	2.045	40.448	4.731

	With FACTS devices					
	Maximize TTC		Minimize loss		Max. TTC &min loss	
Method	TTC	Loss	TTC	Loss	TTC	Loss
EP	125.531	3.921	17.500	1.296	126.021	3.914
TS	126.274	3.725	17.500	1.281	126.755	3.793
TS/SA	127.113	3.880	17.500	1.258	127.415	3.715
IEP	128.675	3.176	17.500	1.154	133.919	2.827
HEA	147.322	4.152	17.500	1.096	154.061	3.607

Table 3

TTC level & TTC value of multilateral transaction on the modified IEEE 118-bus system

	TTC level (MW) without FACTS devices				
Case	**EP**	**TS**	**TS/SA**	**IEP**	**HEA**
Normal	701.61	703.68	706.17	707.27	710.57
Largest gen. in area 6 outage	656.24	663.68	673.95	669.84	677.84

Largest gen. in area 3 outage	694.29	694.98	703.40	706.12	708.50
Line 38–65 outage	481.08	483.31	483.38	483.68	487.13
Line 42–49 outage	439.55	438.05	456.87	458.40	461.03
Line 44–45 outage	664.59	651.42	655.80	661.85	666.56
Contingency TTC value	439.55	438.05	456.87	458.40	461.03

	TTC level (MW) with FACTS devices					
Case	**EP**	**EP**	**TS**	**TS/SA**	**IEP**	**HEA**
Normal	701.61	706.81	718.21	721.27	720.01	725.17
Largest gen. in area 6 outage	656.24	674.11	687.29	687.29	690.45	695.08
Largest gen. in area 3 outage	694.29	708.67	705.20	712.88	723.36	733.64
Line 38–65 outage	481.08	486.75	484.96	487.94	498.87	513.62
Line 42–49 outage	439.55	481.07	475.87	497.45	493.48	520.76
Line 44–45 outage	664.59	671.73	661.08	668.70	683.75	688.79
Contingency TTC value	439.55	481.07	475.87	487.94	493.48	513.62

Table 4

TTC results & CPU times of multilateral transaction on the modified IEEE 30-bus system

Without FACTS devices					
TTC (MW)					
Method	**Best**	**Average**	**Worst**	**deviation**	**CPU time (min)**
EP	125.663	124.205	121.891	1.48	0.71
TS	125.781	125.339	124.796	0.31	0.62
TS/SA	125.781	125.339	124.796	0.31	0.62
IEP	125.716	125.349	124.840	0.32	0.77
HEA	125.930	125.351	124.923	0.31	0.75

With FACTS devices					
TTC (MW)					
Method	Best	Average	Worst	Standard deviation	CPU time (min)
EP	136.040	129.790	121.937	5.46	3.11
TS	157.389	142.263	125.554	12.68	2.58
TS/SA	157.389	142.263	125.554	12.68	2.58
IEP	165.545	142.758	130.716	10.55	4.26
HEA	191.379	170.497	156.352	9.83	4.17

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