AVAILABLE TRANSFER CAPABILITY COMPUTATIONS IN THE INDIAN SOUTHERN E.H.V POWER SYSTEM USING INTELLIGENT TECHNIQUES

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Abstract

This paper presents three methods for computing the available transfer capability (ATC). One method is the conventional method known as continuation repeated power flow (CRPF) and other two are the intelligent techniques known as radial basis function neural network (RBFNN), basic adaptive neuro fuzzy inference system (ANFIS). In these two intelligent techniques, the basic ANFIS works with a multiple input single output (MISO) and it is modified as multiple input multiple output (MIMO) ANFIS using the proposed MIMO ANFIS. The main intension of this proposed method is to utilise the significant features of ANFIS with respect to the multiple outputs, as the basic ANFIS has been proved as the best intelligent techniques in the modelling of any application, but it has a disadvantage of single output and this drawback will be overcome using the proposed MIMO ANFIS. In this paper, the latest Indian southern region extra high voltage (SREHV) 72-bus system considered as test system to obtain the ATC computations using three methods. The ATC computations at desired buses are obtained with and without contingencies and compared the conventional ATC computations with the intelligent techniques. The obtained results are scrupulously verified with different test patterns and observed that the accuracy of proposed method is proved as the best as compared to the other methods for computing ATC. In this way, this paper shows a better way to compute ATC for the different open power market system

Keywords— *Available Transfer Capability, Total Transfer Capability, Open Power Markets, Repeated Power Flow, Radial Basis Function Neural Networks, Adaptive Neuro Fuzzy Inference System etc.*

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1. INTRODUCTION

The time to time computations of available transfer capability (ATC) becomes a significant and challenging issue in the development of open power markets across the world [1]. To solve this issue using the existing conventional methods such as Repeated Power Flow (RPF) [2], Continuation Power Flow (CPF), Transfer based Security Constrained Optimal Power Flow (TSCOPF) [3], Optimal Power Flow (OPF) ,Network Response method [4], Rated System Path method [5], Linear ATC (LATC) method [6], ATC by Comprehensive method [7] and DC Power Flow Method[8], cannot be trusted in smooth operation of the power system because these are depend on mathematical equations [9]. Even though these methods will provide the base information related to the steady state operation of power system, they fail to afford the on-line information due to the involvement of iteration steps towards the convergent point. This drawback would be overcome by intelligent techniques, which are the most useful techniques to obtain precise and necessary information when they are trained properly related to the computations of ATC [10].

The ATC calculations play a vital role in the open power market transactions and during blackouts the ATC between two areas provides an indication of the amount of additional electric power that can be transferred from one area to another for a specific time frame, for a specific set of conditions. ATC can be a very dynamic quantity because it is a function of variable and interdependent parameters [11]. These parameters are highly dependent upon the conditions of the network. Consequently, ATC calculations may need to be periodically updated; it is possible only by using intelligent techniques because of their proved performance in the on-line conditions.

Artificial Neural Networks (ANN) is an emerging Artificial Intelligence technique. An ANN is a massively parallel information-processing system and it can perform nonlinear computations in a short duration after it has trained with the sufficient data. ANN has found many applications in Power Systems [12]. With respect to all available intelligent techniques, each individual technique will be strong enough in its specific property and its implementation related to a specific application. In this regard, the neural networks are the best suitable in non-linear function related applications, that is, they are the best for modelling of any application such as voltage stability analysis, computations of available transfer capability, load forecasting, power quality analysis, power system fault diagnosis and so on. In the ANN, the Radial Basis Function Neural Networks (RBFNN), Back Propagation Neural Networks (BPNN) and Adaptive Neuro Fuzzy Inference Systems (ANFIS) are the popular to model the behaviour of any system. In this paper, the RBFNN and ANFIS are used to compute the ATC.

The remaining sections of this paper are organized as follows: Section II briefly discusses the ATC. The section III describes the RBFNN and ANFIS. The section IV deliberates the methods used to compute ATC along with a proposed MIMO ANFIS. The section V presents SREHV 72-bus test system and different case scenarios to obtain the results from three methods. Finally, section VI presents useful conclusions.

2. AVAILABLE TRANSFER CAPABILITY

The Available Transfer Capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above previously committed uses [13]. Mathematically, ATC is defined as the Total Transfer Capability (TTC) less the Transmission Reliability Margin (TRM) and the Capacity Benefit Margin (CBM).

$$ATC = TTC - TRM - CBM \quad (1)$$

Total Transfer Capability (TTC) is defined as the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner while meeting all of a specific set of defined pre and post-contingency system conditions.

Transmission Reliability Margin (TRM) is defined as that amount of transmission transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.

Capacity Benefit Margin (CBM) is defined as that amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirements.

3. INTELLIGENT TECHNIQUES

In this paper, the following two intelligent techniques used to compute available transfer capability.

3.1 Radial Basis Function Neural Networks (RBFNN)

The architecture of Radial Basis Function Neural Network (RBFNN) consists of input layer, hidden layer and output layer [14]. The RBFNN has become increasingly popular because it is the best function approximation technique and is used for modelling of any type of applications, which are related to any field [15]. The RBFNN mainly uses the activation function represented with equation (2) to its hidden neurons.

$$\varphi_i = \exp\left(-\frac{\sum_{i=1}^{n}(x_i - w_{ij})^2}{2\sigma^2}\right) \quad (2)$$

3.2 Training Algorithm of RBFNN

Step 1: Start training RBFNN.
Step 2: Declare and initialise all variables such as input vector (x_i), output of input layer $O_{il,}$ output of hidden layer $O_{hl,}$ output of output layer $O_{ol,}$ targeted output vector (O_i), initial assumed weights (W_{ij}), change of weight (ΔW_{ij}), hidden neuron's activation function φ_i , spread of RBFNN (σ), learning rate factor (η), error term (e), iteration number (i) and number of epochs (n).
Step 3: Process the input vector x_i to the input layer of RBFNN and calculate the output of input layer using $O_{il} = f(x_i) = m\, x_i$.
Step 4: Process the output of input layer O_{il} to the hidden layer of RBFNN and calculate the output of the hidden layer O_{hl} using equation 2.
Step 5: Process the output of hidden layer O_{hl} to the output layer of RBFNN and calculate the output of output layer O_{ol} using equation 2.
Step 6: Calculate the error (e) and change in weight $\Delta W_{ij}(k)$ using $e = O_i - O_{ol}$ and $\Delta W_{ij}(k) = \eta\, e\, x_i$
Step 7: Update initial weight matrix Wij using $W_{ij}(K+1) = W_{ij}(k) + \Delta W_{ij}(k)$
Step 8: Repeat the step 3 to step 7 until the error is minimised to zero or there is no further chance of updating the weights W_{ij}.
Step 9: Stop training RBFNN.

To accomplish the best training efficiency from RBFNN, the prerequisite is the training data and checking data (data patterns), which are generally obtained from the simulation results of conventional load flow using Newton-Raphson's method or the similar type of practical data can be obtained from any load dispatch center. For training ATC training data consists of real power values (P_i) as the inputs and TTC, ATC, Convergence Status (C.S) as the outputs at various buses. With these the RBFNN will undergo for training, once the desired goal is reached, the trained RBFNN would undergo for the checking of its performance with the checking data called as test patterns. Once the results obtained from the trained RBFNN are accurate then that trained RBFNN will be used for computing ATC with any new input data.

3.3 Adaptive Neuro Fuzzy Inference System (ANFIS)

The Adaptive Neuro-Fuzzy Inference System (ANFIS) combines the concepts of fuzzy logic and neural networks to form a hybrid intelligent system that enhances the ability to automatically learn and adapt [16]. Hybrid systems have been used by researchers for modelling and predictions in various engineering systems. The basic idea behind these Neuro-adaptive learning techniques is to provide a method for the fuzzy modelling procedure to learn information about a data set, in order to automatically compute the membership function parameters that best allow the associated Fuzzy Inference System (FIS) to track the given input/output data. Similar to the RBFNN, the ANFIS also used to compute ATC using a proposed method as discussed in the section IV (C).

4. METHODS TO COMPUTE ATC

In addition to the various methods discussed in the section I, the following methods are used to obtain results presented in this paper.

4.1 Method-1: ATC by Continuation Repeated Power Flow (CRPF ATC)

In this method, the Newton Raphson's method in polar coordinates [17] is used to compute the TTC and ATC at different load increments (with constant power) on the desired load bus of different test systems. As this same method is repeated for different load increments thus this method is called as the repeated power flow (RPF), if the automatic increment of loading continues till maximum loading point is called as continuation repeated power flow (CRPF).

4.2 Method-2: ATC using Trained RBFNN (RBFNN ATC)

In this method, the training algorithm as discussed in the section III (B) has been used to train the RBFNN with the training data obtained from conventional method as discussed in the section IV (A). The training data consisting real power values (P_i) as the inputs and TTC, ATC, Convergence Status (C.S) as the outputs at various buses. The RBFNN is trained with these data patterns, once the desired goal is reached, its performance is verified with the checking data (test patters). The results obtained from the trained RBFNN are accurate then it is said to be ATC computations are achieved using RBFNN.

4.3 Method-3: ATC using Proposed MIMO ANFIS (ANFIS ATC)

The proposed multiple input and multiple output ANFIS (MIMO ANFIS) as shown in Fig. 1 is developed and tested scrupulously by cascading three single input, single output ANFIS through well-defined programming. This proposed method will overcome the drawback of single output of ANFIS, so that multiple outputs will be obtained from the ANFIS. The proposed technique will become a great advantage to the ANFIS, because ANFIS is having an ability to automatically learn and adapt to non-linearity and the ANFIS has been proved as the best intelligent technique in modelling applications. Similar to method-2, the method-3 also need the same set of training data and checking data as discussed in method-2

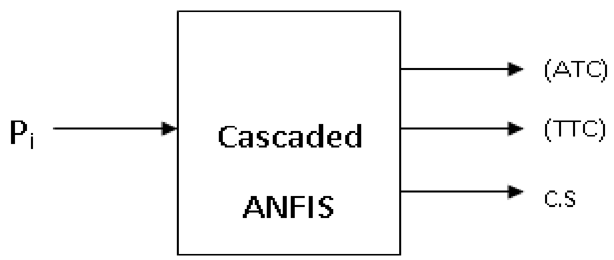

Fig. 1 Block diagram of proposed MIMO ANFIS

5. TEST SYSTEM AND RESULTS

5.1 Test System: Southern Region Extra High Voltage (SREHV) 72-bus system

The latest SREHV 72-bus [18] as shown in Fig. 2 is considered as the test system to compute ATC using various methods as discussed in the section-IV. This test system has divided into three areas ZONE-1, ZONE-2 and ZONE-3. Buses 2, 3, 5, 16, 24, 25, 30, 31, 33, 35, 36, 44, 45, 54, 56, 57, 58 are in ZONE-1. Buses 1, 6, 7, 8, 17, 18, 19, 20, 21, 22, 23, 26, 27, 32, 46, 47, 52, 55, 59, 60, 61, 62, 63, 66, 69, 70 are in ZONE-2. Buses 9, 10, 11, 12, 13, 14, 15, 28, 29, 34, 37, 38, 39, 40, 41, 42, 43, 48, 49, 50, 51, 53, 64, 65, 67, 68, 71, 72 are in ZONE-3. Buses 1 to 15 are generator buses. Buses 16, 17, 18, 19, 20, 21, 22, 23, 25, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 48, 49, 52, 53, 54, 55, 64, 65, 66, 68, 69, 71, 72 are the load buses. The remaining buses are used for interconnection.

5.2 Case Scenarios for Method-1:

For contingency cases, a line outage between bus-9 to bus-11 is created and is considered as contingency.

5.2.1 Case 1: Varying Load at Bus-20 without contingency

In this case, the load at bus-20 is varied with a constant power factor, the corresponding TTC and ATC results obtained through method-1 are presented in Table I and the variation between real power and ATC value can be observed in Fig. 3.

5.2.2 Case 2: Varying Load at Bus-20 with contingency

Similar to case-1, the corresponding TTC and ATC results are presented in Table II and the variation between real power and ATC value can be observed in Fig. 4.

5.2.3 Case 3: Varying Load at Bus-34 without contingency

In this case, the load at bus-34 is varied with a constant power factor, the corresponding TTC and ATC results obtained through method1 are presented in Table III and the variation between real power and ATC value can be observed in Fig. 5.

5.2.4 Case 4: Varying Load at Bus-34 with contingency

Similar to case-3, the corresponding TTC and ATC results are presented in Table IV and the variation between real power and ATC value can be observed in Fig. 6.

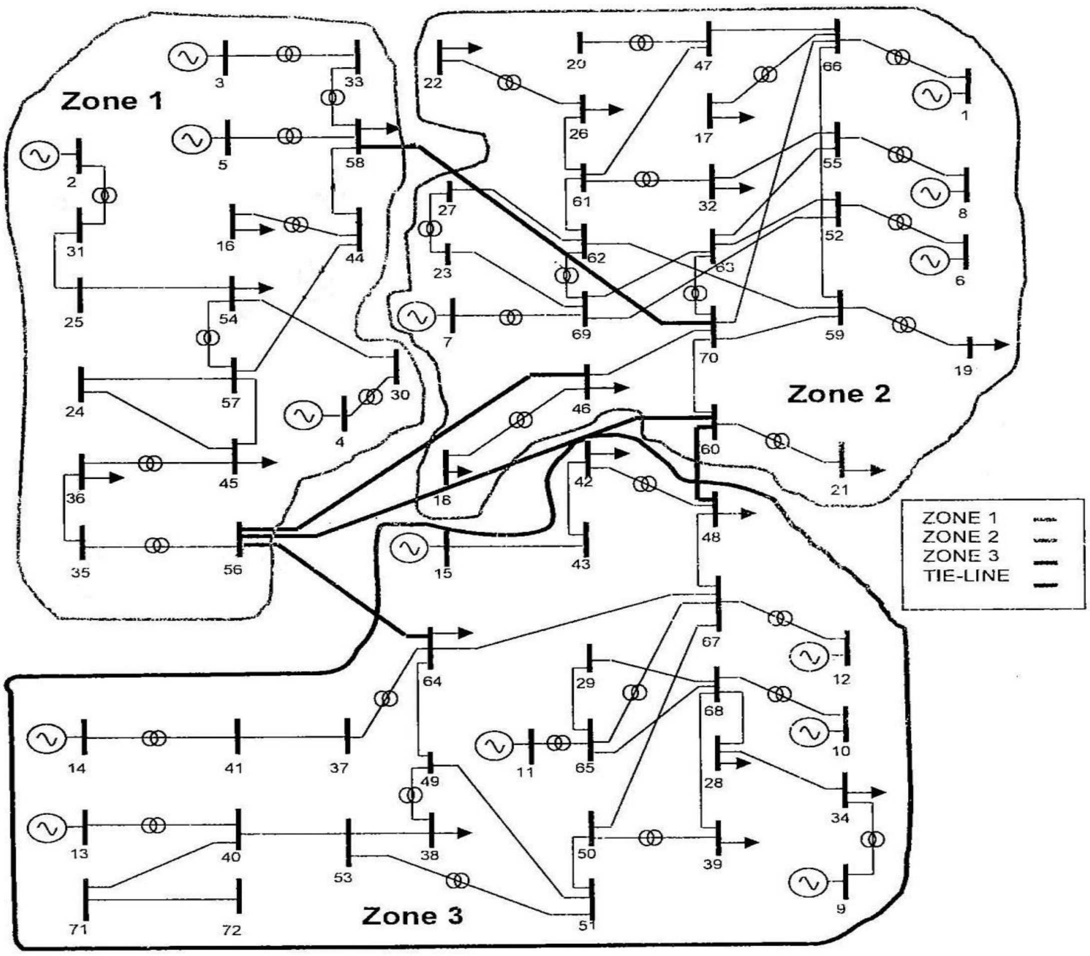

Fig. 2 Single Line Diagram of SREHV 72-Bus Test System

5.3 Case Scenarios for Method-2 and Method-3

For contingency cases, a line outage between bus-9 to bus-11 is created and is considered as contingency.

5.3.1 Case 1: Varying Load at Bus-20 without contingency

In this case, the load at bus-20 is enhanced differently as compared with the training data of two intelligent techniques as discussed in the section IV (B) and IV (C). The comparative results between method-1 vs. method-2 and method-1 vs. method-3 are presented in the Table V and Table IX respectively. The variation between real power and ATC using method-1 vs. method-2 and method-1 vs. method-3 are shown in Fig. 7 and Fig. 11 respectively.

5.3.2 Case 2: Varying Load at Bus-20 with contingency

Similar to case-1, the corresponding results obtained through method-2 and method-3 are compared with the method-1. The comparative results between method-1 vs. method-2 and method-1 vs. method-3 are presented in the Table VI and Table X respectively. The variation between real power and ATC using method-1 vs. method-2 and method-1 vs. method-3 are shown in Fig. 8 and Fig. 12 respectively.

5.3.3 Case 3: Varying Load at Bus-34 without contingency

In this case, the load at bus-34 is enhanced differently as compared with the training data of two intelligent techniques as discussed in the section IV (B) and IV (C). The comparative results between method-1 vs. method-2 and method-1 vs. method-3 are presented in the Table VII and Table XI respectively. The variation between real power and ATC using method-1 vs. method-2 and method-1 vs. method-3 are shown in Fig. 9 and Fig. 13 respectively.

5.3.4 Case 4: Varying Load at Bus-34 with contingency

Similar to case-3, the corresponding results obtained through method-2 and method-3 are compared with the method-1. The comparative results between method-1 vs. method-2 and method-1 vs. method-3 are presented in the Table VIII and Table XII respectively. The variation between real power and ATC using method-1 vs. method-2 and method-1 vs. method-3 are shown in Fig. 10 and Fig. 14 respectively.

5.4 Results

The TRM and CBM used in the equation (1) are often represents to the existing transmission commitments. In the power flow studies this existing transmission commitments are usually represented as base load at particular bus. Thus in this paper, the ATC is computed as ATC=TTC- Base Load. The MATPOWER 4.1open software package [19] and the MATLAB [20]programming environment has been used to obtain the results for different case scenarios.

5.4.1 Method-1 CRPF ATC Data for SREHV 72-Bus System

Table 1 ATC Data for variation of load at bus-20 without contingency

Complex Power S_{20} (MVA)	TTC2 (MW)	ATC2 (MW)	C.S
80.00 + j 55.61	2225.42	17.8	YES
100.00 + j 69.52	2245.42	37.8	YES
300.00 + j 208.55	2445.42	237.8	YES
700.00 + j 486.62	2845.42	637.8	YES
808.30 + j 561.91	**2953.72**	**746.1**	**YES**
808.40 + j 561.98	2953.73	746.2	NO

Table 2 ATC Data for variation of load at bus-20 with contingency

Complex Power S_{20} (MVA)	TTC2 (MW)	ATC2 (MW)	C.S
80.00 + j 55.61	2225.42	17.8	YES
100.00 + j 69.52	2245.42	37.8	YES
300.00 + j 208.55	2445.42	237.8	YES
700.00 + j 486.62	2845.42	637.8	YES
803.20 + j 558.37	**2948.62**	**741**	**YES**
803.30 + j 558.44	2948.63	741.1	NO

Table 3 ATC Data for variation of load at bus-34 without contingency

Complex Power S_{34} (MVA)	TTC3 (MW)	ATC3 (MW)	C.S
360.00 + j 54.93	3272.69	14.39	YES
420.00 + j 64.08	3332.69	74.39	YES
560.00 + j 85.44	3472.69	214.39	YES
700.00 + j 106.80	3612.69	354.39	YES
859.02 + j 131.06	**3771.69**	**513.39**	**YES**
859.03 + j 131.06	3771.70	513.40	NO

Table 4 ATC Data for variation of load at bus-34 with contingency

Complex Power S_{34} (MVA)	TTC3 (MW)	ATC3 (MW)	C.S
360.00 + j 54.93	3272.69	14.39	YES
420.00 + j 64.08	3332.69	74.39	YES
560.00 + j 85.44	3472.69	214.39	YES
700.00 + j 106.80	3612.69	354.39	YES
857.60 + j 130.84	**3770.29**	**511.99**	**YES**
857.70 + j 130.86	3770.39	512.09	NO

5.4.2 Method-1 CRPF ATC Figures for SREHV 72-Bus System

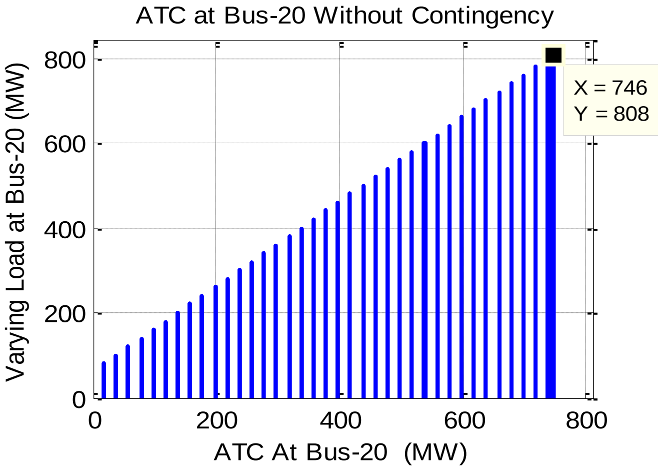

Fig. 3 ATC Bar plot for increasing Load at Bus-20 without Contingency

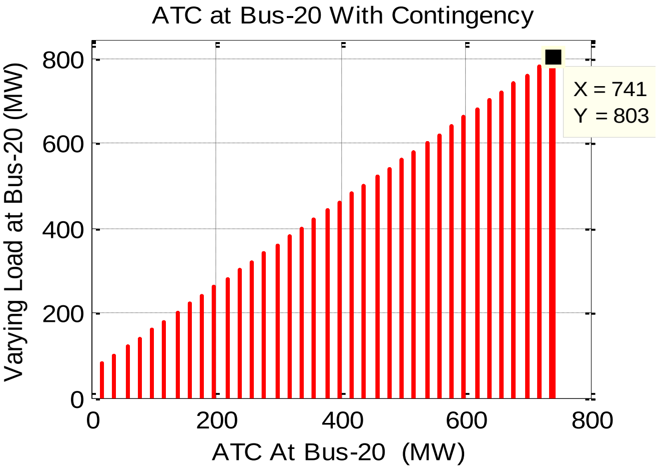

Fig. 4 ATC Bar plot for increasing Load at Bus-20 with Contingency

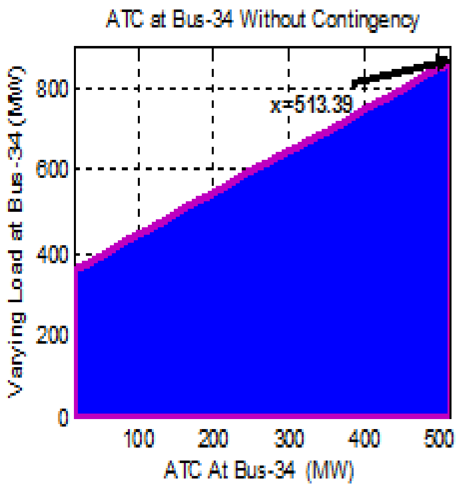

Fig. 5 ATC Area plot for increasing Load at Bus-34 without Contingency

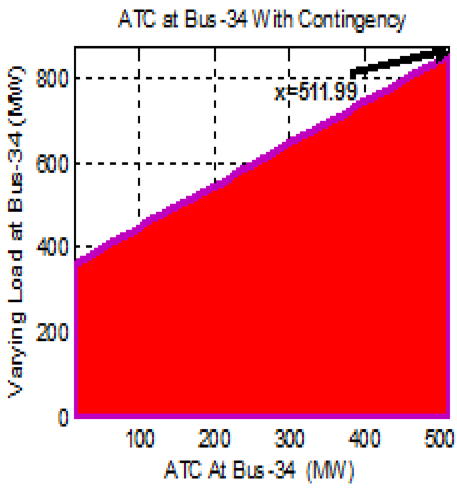

Fig. 6 ATC Area plot for increasing Load at Bus-34 with Contingency

5.4.3 Method-2 RBFNN ATC Data for SREHV 72-Bus System

Table 5 Data for variation of load at bus-20 without contingency

Test Patterns (Checking Data)	Real Power P_{20} (MW)	CRPF METHOD			RBFNN METHOD			% ATC Error
		TTC2 (MW)	ATC2 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	105	2250.42	42.8	1	2250.421	42.80105	1	-0.00245
2	280	2425.42	217.8	1	2425.42	217.8	1	0.000
3	455	2600.42	392.8	1	2600.42	392.8	1	0.000
4	630	2775.42	567.8	1	2775.42	567.8	1	0.000
5	**805**	**2950.42**	**742.8**	**1**	**2950.42**	**742.8**	**1**	**0.000**
6	808.7	2954.12	746.5	0	2954.12	746.5	0	0.000

$$\% \text{ ATC Error} = \frac{\text{Reference ATC - Obtained ATC}}{\text{Obtained ATC}} \times 100 = \frac{42.8 - 42.80105}{42.801055} \times 100 = -2.45 \times 10^{-3}$$

Table 6 Data for variation of load at bus-20 with contingency

Test Patterns (Checking Data)	Real Power P_{20} (MW)	CRPF METHOD			RBFNN METHOD			% ATC Error
		TTC2 (MW)	ATC2 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	105	2250.42	42.8	1	2250.421	42.80109	1	-0.00255
2	630	2775.42	567.8	1	2775.42	567.8	1	0.000
3	787	2932.42	724.8	1	2932.42	724.8	1	0.000
4	803	2948.42	740.8	1	2948.42	740.8	1	0.000
5	**803.2**	**2948.62**	**741**	**1**	**2948.62**	**741**	**1**	**0.000**
6	803.5	2948.92	741.5	0	2948.92	741.5	0	0.000

Table 7 Data for variation of load at bus-34 without contingency

Test Patterns (Checking Data)	Real Power P_{34} (MW)	CRPF METHOD			RBFNN METHOD			% ATC Error
		TTC3 (MW)	ATC3 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	385	3297.69	39.39	1	3297.691	39.39104	1	-0.00264
2	560	3472.69	214.39	1	3472.69	214.39	1	0.000
3	700	3612.69	354.39	1	3612.69	354.39	1	0.000
4	840	3752.69	494.39	1	3752.69	494.39	1	0.000
5	**859**	**3771.69**	**513.39**	**1**	**3771.69**	**513.39**	**1**	**0.000**
6	860	3772.69	514.39	0	3772.69	514.39	0	0.000

Table 8 Data for variation of load at bus-34 with contingency

Test Patterns (Checking Data)	Real Power P_{34} (MW)	CRPF METHOD			RBFNN METHOD			% ATC Error
		TTC3 (MW)	ATC3 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	385	3297.69	39.39	1	3297.691	39.39102	1	-0.00259
2	560	3472.69	214.39	1	3472.69	214.39	1	0.000
3	770	3682.69	424.39	1	3682.69	424.39	1	0.000
4	857.1	3769.79	511.49	1	3769.79	511.49	1	0.000
5	**857.6**	**3770.29**	**511.99**	**1**	**3770.29**	**511.99**	**1**	**0.000**
6	857.7	3770.39	512.09	0	3770.39	512.09	0	0.000

5.4.4 Method-2 RBFNN ATC Figures for SREHV 72-Bus System

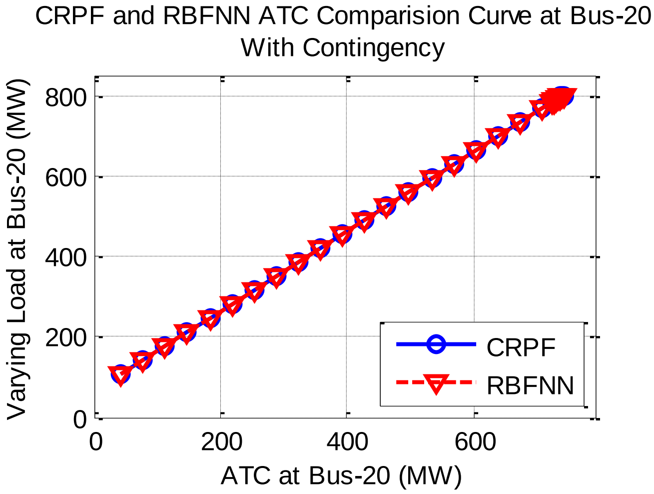

Fig. 7 CRPF and RBFNN ATC Plot for increasing Load at Bus-20 without Contingency

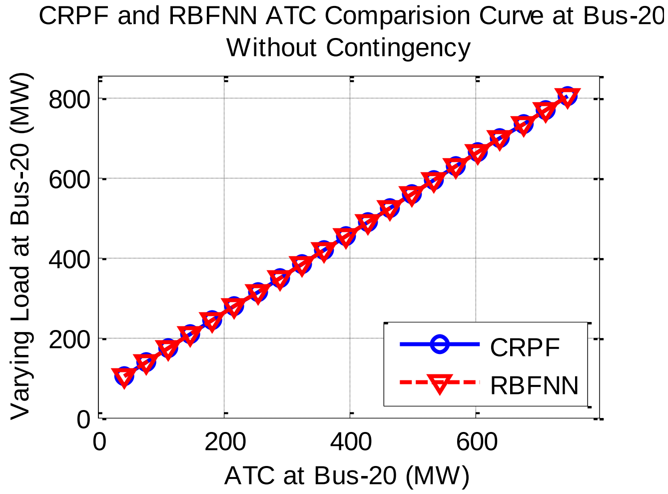

Fig. 8 CRPF and RBFNN ATC Plot for increasing Load at Bus-20 with Contingency

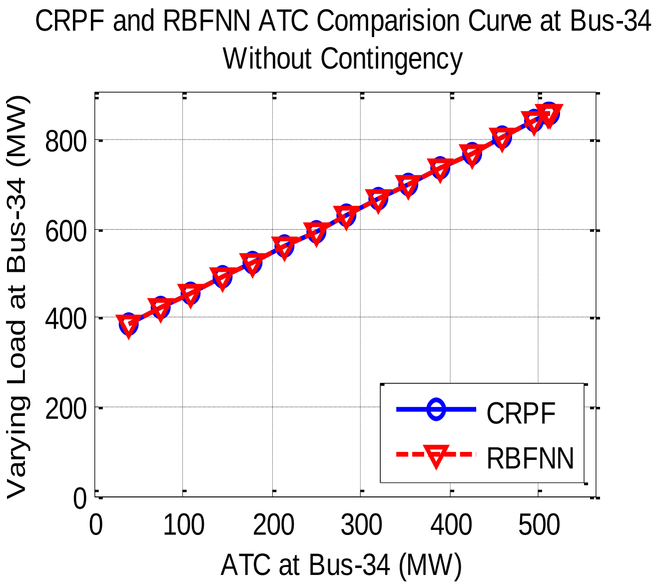

Fig. 9 CRPF and RBFNN ATC Plot for increasing Load at Bus-34 without Contingency

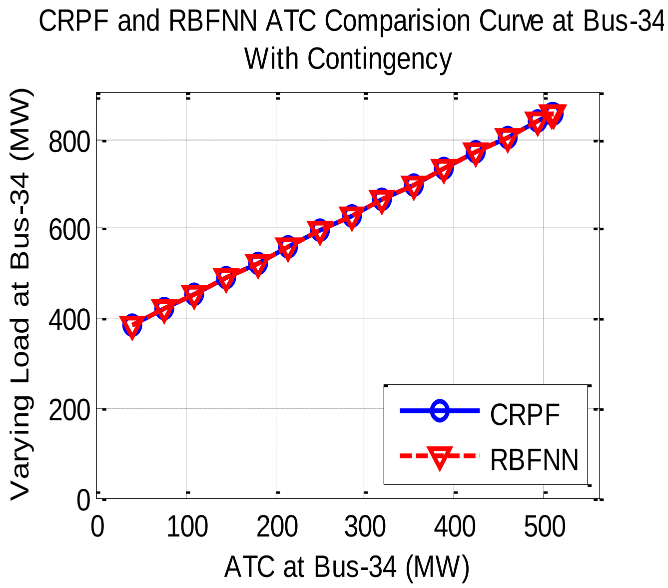

Fig. 10 CRPF and RBFNN ATC Plot for increasing Load at Bus-34 with Contingency

5.4.5 Method-3 ANFIS ATC Data for SREHV 72-Bus System

Table 9 Data for variation of load at bus-20 without contingency

Test Patterns (Checking Data)	Real Power P_{20} (MW)	CRPF METHOD			ANFIS METHOD			% ATC Error
		TTC2 (MW)	ATC2 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	105	2250.42	42.8	1	2250.42	42.80003	1	0.000
2	280	2425.42	217.8	1	2425.42	217.8	1	0.000
3	455	2600.42	392.8	1	2600.419	392.8	1	0.000
4	630	2775.42	567.8	1	2775.421	567.8	1	0.000
5	**805**	**2950.42**	**742.8**	**1**	**2950.42**	**742.8**	**1**	**0.000**
6	808.7	2954.12	746.5	0	2954.12	746.5	0	0.000

Table 10 Data for variation of load at bus-20 with contingency

Test Patterns (Checking Data)	Real Power P_{20} (MW)	CRPF METHOD			ANFIS METHOD			% ATC Error
		TTC2 (MW)	ATC2 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	105	2250.42	42.8	1	2250.42	42.80004	1	0.000
2	630	2775.42	567.8	1	2775.421	567.8	1	0.000
3	787	2932.42	724.8	1	2932.42	724.8	1	0.000
4	803	2948.42	740.8	1	2948.419	740.8	1	0.000
5	**803.2**	**2948.62**	**741**	**1**	**2948.619**	**741**	**1**	**0.000**
6	803.5	2948.92	741.5	0	2948.92	741.5	0	0.000

Table 11 Data for variation of load at bus-34 without contingency

Test Patterns (Checking Data)	Real Power P_{34} (MW)	CRPF METHOD			ANFIS METHOD			% ATC Error
		TTC3 (MW)	ATC3 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	385	3297.69	39.39	1	3297.688	39.39034	1	0.000
2	560	3472.69	214.39	1	3472.692	214.3897	1	0.000
3	700	3612.69	354.39	1	3612.687	354.3904	1	0.000
4	840	3752.69	494.39	1	3752.69	494.3899	1	0.000
5	**859**	**3771.69**	**513.39**	**1**	**3771.691**	**513.3899**	**1**	**0.000**
6	860	3772.69	514.39	0	3772.69	514.39	0	0.000

Table 12 Data for variation of load at bus-34 with contingency

Test Patterns (Checking Data)	Real Power P_{34} (MW)	CRPF METHOD			ANFIS METHOD			% ATC Error
		TTC3 (MW)	ATC3 (MW)	C.S	TTC (MW)	ATC (MW)	C.S	
1	385	3297.69	39.39	1	3297.689	39.39021	1	0.000
2	560	3472.69	214.39	1	3472.689	214.39	1	0.000
3	770	3682.69	424.39	1	3682.692	424.3897	1	0.000
4	857.1	3769.79	511.49	1	3769.789	511.4901	1	0.000
5	**857.6**	**3770.29**	**511.99**	**1**	**3770.289**	**511.9901**	**1**	**0.000**
6	857.7	3770.39	512.09	0	3770.39	512.09	0	0.000

5.4.6 Method-3 ANFIS ATC Figures for SREHV 72-Bus System

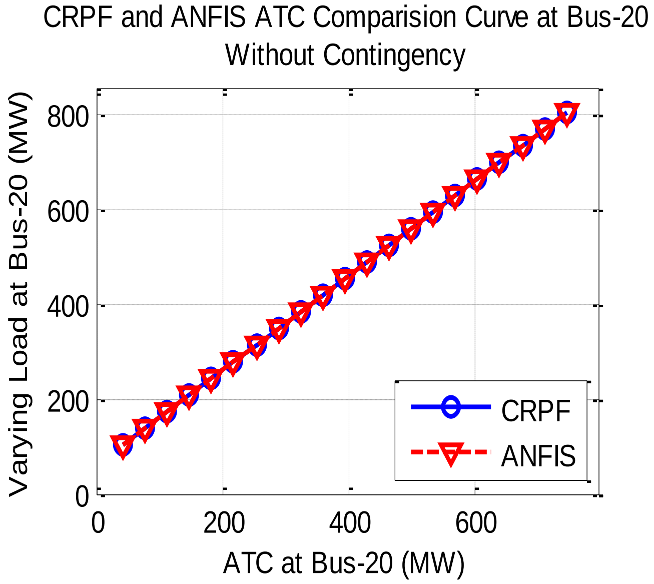

Fig. 11 CRPF and ANFIS ATC Plot for increasing Load at Bus-20 without Contingency

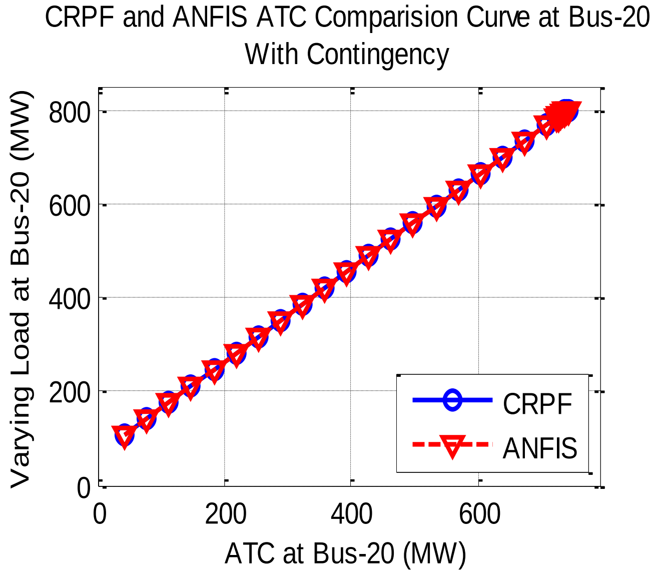

Fig. 12 CRPF and ANFIS ATC Plot for increasing Load at Bus-20 with Contingency

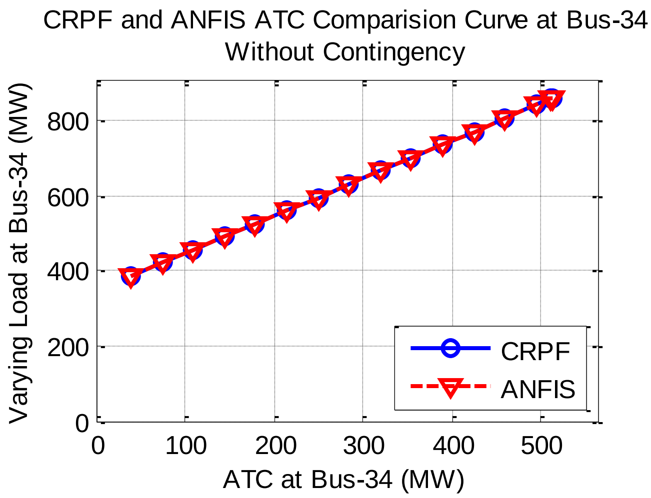

Fig. 13 CRPF and ANFIS ATC Plot for increasing Load at Bus-34 without Contingency

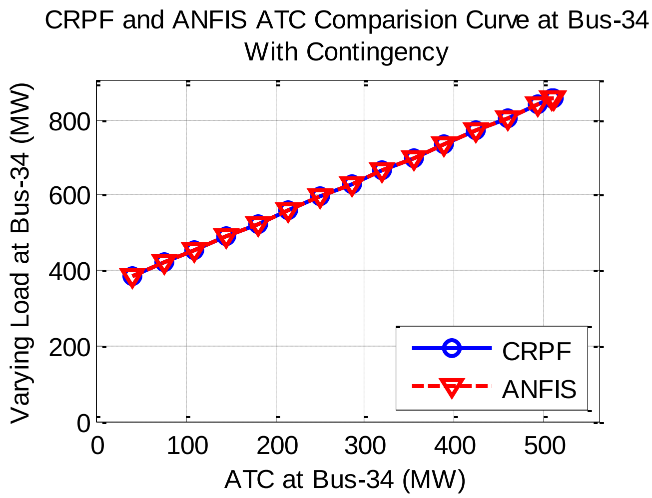

Fig. 14 CRPF and ANFIS ATC Plot for increasing Load at Bus-34 with Contingency

6. CONCLUSION

In this paper, the latest Indian southern region extra high voltage 72-bus system used to compute the ATC at the desired buses starting from the base loading point to till the maximum loading point. The ATC obtained at this maximum loading point is called as voltage stability constrained ATC (VSC ATC), this ATC is maximum ATC at the desired buses and it has been marked as bold in the different tables and figures presented in this paper. From these results it has observed that the amount of VSC ATC is less for the contingency cases. The results obtained from the continuation repeated power flow are used to train the radial basis function neural network (RBFNN) and proposed MIMO adaptive neuro fuzzy inference system (MIMO ANFIS). After satisfied training of RBFNN and MIMO ANFIS, the performance of these intelligent techniques are verified with respect to different test patterns. These test patterns and comparative results indicating that the results obtained through the RBFNN and proposed MIMO ANFIS are accurate because the percentage of error is almost zero. It has proved in this paper with the number of case scenarios. Hence for computing ATC in the case of on-line environment the RBFNN and proposed ANFIS can be used due to their superior advantages over the conventional methods. From the results it has been proved that the level of accuracy is more in the case of proposed MIMO ANFIS when compared with the RBFNN and also the ANFIS will have the superior system modelling features as compared with RBFNN. During the open power markets the computation of ATC will becoming a significant feature and its value is a dynamic phenomenon, in this type of situations till depending on steady state computations would not provide precise ATC values. Therefore this paper suggesting the proposed the MIMO ANFIS will be the best for computing ATC for the different power markets as compared with the other existing methods.

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