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A HYBRID EXPERT SYSTEM ASSISTING DECISION MAKING FOR DISTRIBUTION SYSTEM LOAD FORECASTING

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Abstract.--This paper introduces a typically intelligent hybrid expert system (ES) for an annualized distribution system load forecasting. The proposed ES has the capability of predicting the annual distribution substation load growth, and patterns of subsequent load shifts, in case of a substation overload. Also, possible expected system expansion plans are introduced. The parameters of the load growth model are estimated for each substation. The load transfer model is chosen to follow the Weibuil distribution function and to simulate different factors affecting the transfer process. The ES is developed using an artificial intelligence language (PROLOG), and is applied to Alexandria city, 66/11 KV power distribution network.

I. INTRODUCTION

Load forecast plays an important role in all aspects of electric utility operations. In particular, distribution system load forecast (DSLF), for a number of forecast years to a defined horizon year, is necessary for maintaining an efficient and reliable power distribution system (DS). Proper analysis of the locations and amounts of future load growth, as well as the expected transfer, are important since they can impact the expansion of the DS.

A variety of computerized load forecasting methods for distribution planning has been developed during the last decade [1] through [4], [6]. Distribution planning is usually met by dividing the utility service area into a number of sufficiently small areas [2]. Those areas can be either a grid of uniform rectangular cells, or equipment oriented areas, such as feeders or substations areas. A load forecast for each area is then produced and finally, the future system can be planned. Generally DSLF is performed using one of the following basic approaches:

1-Trending methods which involve extrapolation of annual peak load history on a small area basis using curve fitting.

2-Multivariate techniques which encompass methods that extrapolate on the basis of other variables as well as the annual peak load. This can be applied on large utility systems and give good results.

3-Simulation approaches which generally work by predicting the load on a small area basis after the customer is classified as residential, commercial, or industrial.

In this paper, a hybrid heuristic/mathematical algorithm is developed to implement a coupled annualized load growth and load transfer for the distribution system. The developed ES performs the following tasks:

1-A load growth forecast for each substation area, with the calculation of the associated model parameters using a nonlinear least square estimation algorithm [20].

2-A load transfer process, including descriptors of the expected load transfer to model separation distances, geographical obstacles, saturated corridors, etc.

3-A proposed system expansion plan, with a load transfer process in case of a new substation addition to the system under study.

In addition to the above tasks, the developed ES also includes a method for measuring the goodness of fit of the historical data for each substation. Also a provision that permits adjustments of the individual small areas yearly forecast to meet a specified total area demand is included in the body of the knowledge base. The proposed ES allows the user to observe each substation load growth every year within the defined horizon, and the overloaded substation (if any). When an overload is predicted the ES proposes solutions that can be adopted for relieving that overloaded substation. It also allows the user to interfere during the algorithm execution to update the ES knowledge base or redirect the solution path whenever is required. This paper is organized as follows. A review of the structure of the proposed ES is given in section II. Mathematical models are developed in section III. The proposed search strategy is depicted in section IV. A typical case study is given in section V. Conclusions and references are given in sections VI and VII respectively.

II. STRUCTURE OF THE PROPOSED ES

A simplified diagram that shows the components of a typical ES is shown in Fig. 1. In the present work, the developed ES is divided into two modules; (1) A knowledge base

(2) An inference engine and user interface (shell)

The knowledge base comprises the fact and rule bases. It contains information specific to the application considered (load growth, load transfer, substation addition). Details concerning the knowledge base are extended in section IV. The inference engine uses its capabilities to satisfy the examined rules. The inference mechanism operates through forward or backward chaining. The user interface represents the explanatory part that allows the user to interfere with the system.



Fig. 1 A Typical Expert System

III. MATHEMATICAL MODELS

The mathematical models [11], [13] for substation load growth and the expected load sharing between substations are summarized as follows

A. Load Growth Model:

The load growth in a small area is not a smooth continuous process. Usually it forms a sharp "burst" of growth taking a few years, resulting in the so called "S" or Gompertz curve [8], [9], [10], [12]. This curve has been shown to adequately model the load growth of urban substations. However, other models are more applicable to particular loads such as industrial substations. The Gompertz model is given by:

$$S(t) - G_A * G_B^{G_C}$$
(1)

where S(t) = function load value for year t. G_A , G_B , G_C are the Gompertz model parameters. In this research, these parameters are calculated for each

substation using a nonlinear least square estimation algorithm (Marquardt

algorithm [20]). This load growth model allows a considerable flexibility of data fitting. Unfortunately there is no statistical measure which can indicate whether the historical data represent an appropriate base for data fitting or not. Thus it is the user responsibility to select from the input only the historical data that is thought to be representative of future years. A method of measuring the goodness of fit of historical data is implemented. This

measure is evaluated by the coefficient of determination R^2 expressed as follows:

$$R^{2} = \frac{\sum_{T=1}^{N} (S_{T} - \overline{S})^{2} - \sum_{T=1}^{N} (S_{T} - S)^{2}}{\sum_{T=1}^{N} (S_{T} - \overline{S})^{2}} * 100$$
(2)

where T = Years of historical data, N = Number of historical points used and S[°] = The mean value for all points. A value close to 100% is indicative of a good fit, whereas a value close to zero is a poor fit. This measure of goodness of fit is evaluated for each substation, and reflects the accuracy level of the forecasted demand.

B. Load Transfer Model:

Load transfer is a function of the distance of separation between substations, age of substations (year of installation), as well as many other factors. A technique similar to Markov process [14], [15], is employed to determine the amount of load transfer between substations. A Weibuil distribution ([16] through [18]) is used to model the expected level of load transfer between substations in terms of their separating distances. This model is given by:

$$F(X) - \left(\frac{W_A}{W_B}\right) \left(\frac{X - W_V}{W_A}\right)^{W_B - 1} \exp\left(-\left(\frac{X - W_V}{W_A}\right)^{W_B}\right) \tag{3}$$

where F (X) is a function value for a random variable X. W_A , W_B , W_V are the Weibull parameters, which represent statistical functions determined by standard and operational practices. The Weibull distribution allows maximum probability of load transfer at some finite inter-separation distance. Further details of the adopted load transfer may be found in [7], [8]. Other factors that express an estimation of the willingness of substations to share load are considered by the proposed ES through the factors (see Appendix A). During the execution of the algorithm, these factors can be adjusted by the user to dictate his view of the system updated situation.

C. Substation Forecast Adjustment:

In order to meet the specified total demand of a large area, adjustments of individual substations projections have to be made. After yearly forecast have been predicted for each substation, the diversified sum can be compared to the total large area forecast. If there is no agreement, each substation forecast would be adjusted as follows:

$$ADJS_{IT} - S_{IT} * \frac{TotS_T}{(DF * \sum_{i=1}^{n} S_{IT})}$$
(4)

where; ADJS_{iT} is the adjustment for substation i at year T, S_{iT} is the

projected demand for substation i at year T, TOtS_T is the total area projected demand for year T, DF is the diversity factor and n is the number of substations considered.

IV. THE ES SEARCH STRATEGY

The first task performed by the proposed ES is a load growth forecasting for each substation. If a substation is found to approach its maximum loading limit at any year (within the forecasting horizon), one of the following solution alternatives will be proposed:

1. Adding further capacity to the heavily loaded substation.

2. Transferring load to one or more of the neighboring substations that already has an excess capacity.

3. Increasing the overall system capacity by adding a new substation, and in most cases, transferring load as well.

These alternatives are ordered according to their economic feasibility, and are handled using a knowledge base frame of work. However, the choice of the proper alternative will be guided by the user through a proper Interface with the ES. The strategy considered for the ES decision making is a depthfirst search technique [23]. This technique is illustrated by the representative tree shown in Fig. 2.



Fig. 2 The Proposed ES Decision Tree

Definitions of the different steps of the search procedure shown in Fig. 2 are summarized as follows.

Step 1: Call data base

Step 2: For each substation calculate the individual load forecast.

Step 3: For each substation check if the load forecast exceeds the specified restricted capacity (RC), where RC is the defined capacity above which the substation is considered overloaded.

 $\underline{D(1)}$: If the load forecast does not exceed RC, then accept the forecast results and continue for the following year.

 $\underline{D(2)}$; If the load torecast does exceed (RC), then one of the following decisions will be proposed:

 $\underline{D(2,1)}$: Expand the capacity of the loaded substation, and modify the data file accordingly if D(2,1,1) and D(2,1,2) are satisfied.

 $\underline{D(2,1,1)}$: The ultimate capacity (UC) is greater then the installed capacity (IC).

D(2.1.2): The system planner accepts D(2,1).

D(2,2): Transfer load to neighboring substations and recalculate the forecast values for all substations using the given load transfer model, if D(2,2,1) and D(2,2,2) are satisfied.

D(2.2.1): The geographical and economical situation allows load transfer. D(2.2.2): The system planner accepts load transfer.

 $\underline{D(2,3)}$: Suggest the addition of a new substation and modify the data file accordingly and reforecast, if D(2,3,1) and D(2,3,2) are satisfied.

 $\underline{D}(2,3,1)$: The neighboring substations approach critical loading.

D(2,3,2): The system planner accepts D(2,3).

The decision tree shown in Fig.2 is formulated in terms of a number of rules. This is explained in the following subsection.

A. Rule Base for the DSLF

The rule base provides tools for calculating different attributes associated with each planning situation. Some of the rules describing the load growth, load transfer and new substation addition processes are given below. I) Rules for Load Growth

UE 1.

IF	Gompertz model
Then	Call the fact base
AND	Calculate the forecasted load growth for year t
AND	Check overload for each substation
RULE 2:	
IF	Calculate the forecasted load for year t
Then	Call FORTRAN program "Gompertz model"
AND	Check overload for all substations
RULE 3:	
IF	Check overload for each substation
Then	Substation unloaded
OR	Substation loaded

<u>RULE 4:</u>	Substation unloaded	OR AND	N L	larkov oaded	transfer model substation	forecast	ng
AND	Ecropert for each substation < restricted capacity	<u>RULE 17:</u>	-	aanam	in installation	of now ei	ihe
IF	defined for the substation under check		5	Conom	installation car	he redu	CA
		OB	1	nadi tra	inster and othe	er overloa	d r
NOLL J.	Substation loaded	On	8	re not	more economi	c	
	Check possibility of capacity addition					-	
IF	Forecast for that substation > RC			V. A	CASE STUDY	Ľ	
 RULE 6:						-	
IF	Check possibility of capacity addition	The proposed	interact	ive loa	d forecasting	of distrib	uti
THEN	Additional capacity	growth and load	I sharing	g meth	odology hand	led by ti	ne
OR	No possible addition	applied to Alexar	ndria City	, 6 6/1	1 KV power di	stribution	ne
<u>RULE 7:</u>		system consists	of 27 si	ubstatio	ns. Some of t	these sub	sta
	Additional capacity	load, according	to the a	ssigned	d tie relation p	parameter	s(s
AND	Increase IC to UC	Each substation	is set to	shift lo	ad to other su	bstations	wt
AND	Modify data files	load exceeds t	he pres	cribed	restricted c	apacity.	Th
IF	It is possible to increase IC	calculations are	presente	d for 1	0 years, follow	ving to y	ear
AND	Planner decision is YES	year. A diverse s	ample o	f result	s are presente	d. Table	1
AND	More economic additional capacity	for each substat	ion [22]	. To s	show the accu	iracy of 1	he
<u>RULE 8:</u>		depicts the load	forecast	for 19	93, compared	with the	g
	It is possible to increase the IC IF	values. A small a	nd practi	cally p	ermitted overlo	ad is ind	ca
	Call the fact base	# 2 for that year.	Table 3	presen	ts the forecast	ed load fo	УŊ
AND	IC _i < UC _i	year the overload	at subs	tation a	# 2 increases	to 4.1664	M
<u>RULE 9:</u>		factors of that su	bstation	with al	I neighboring	ones are	sel
	More economic additional capacity IF	the ES reasoning	propose	es an a	ddition of a ne	w transfo	m
	Not more economic load transfer	to that substation	n. Mean	while o	verloads of 2.	.5809 and	(O
AND	Not more economic installing new substation	indicated at sub	stations	# 11	and 24 respec	ctively. If	τn
RULE 10		reasoning is acce	epted the	n capa	cities of substa	ations #	11
	No possible addition	raised to their ult	imate va	lues (5	0 and 35 MVA) respect	ive
AND	Check load transfer possibility	indicated overload	ds would	be reli	eved. However	, if that pr	op
	Not possible to add capacity	by the user (syst	tem plan	ner), ti	hen the ES wo	oula sugg	es
OR	Planner decision is NU	overload to neigh	boring si	ubstatic	ons. The foreca	sted valu	8S
UR IN Dulas for L	Not economic	takes place are g	iven at t	ne last	column or la	018 3. - Maria 4	~ 4
II) Rules for Lu	ad Transfer to Neighboring Stations:	Results of previo	us tadie	s indic	ate that subsu	ations #	24
ROLE III	Check load transfer possibility to polabboring	subject to rapidly	growing	j loads.	. Adding an ex	100 to 100	1A 1A
	check load transfer possibility to heighborning	to those substation	ons to in	crease	their capacitie	S 10 100	1111
	Substations	In overcoming th		aos on	T-bla 4 Tha b	ichlu cro	us wie
	Looded substation	load for year 200	is are sn	own in	table 4. men	nginy gio Adlation	wii ~f
	No possible addition	In Table 4 direc		s to pr	opose the ins	italiation	-
	Planner decision	substation, and in	ntiating	a loau i	lialisiei as wei		ult
		مغم غمطة غم مميراسي	and with	the pr	w added sub	station (s	ult
		values at that sta	ige, with	the ne	wadded sub	station (s	ult ub:
1E	Planner decision	values at that sta given by the las	ige, with it colum	the ne n of T	able 4. It is the addition	station (s clear that	ult ub:
	Planner decision Call user interface	values at that sta given by the las indicated after th	ige, with it colum e new si	the ne n of T ubstatic	able 4. It is on addition.	station (s clear that	ult ub:
	Planner decision Call user interface No obstacles	values at that sta given by the las indicated after the specification	ige, with it colum is new su	the ne n of T ubstatic	able 4. It is a addition.	station (s clear that kV Distri	
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ion of new substation IF can be reduced other overload relieving methods omic

UDY

ng of distribution systems load andled by the proposed ES is distribution network. The given of these substations may share on parameters(see Appendix A). substations when its forecasted a substations when its forecasted ad capacity. The load forecast ollowing to year 1993 as a base ented. Table 1 summarizes data accuracy of the results, Table 2 ared with the given actual load verload is indicated at substation asted load for year 1997. In this ses to 4.1664 MVA. Since the tle ng ones are set to be 100, then a new transformer (1 X 25) MVA of 2.5809 and 0.02595 MVA are spectively. if the first proposed bstations # 11 and 24 would be MVA) respectively. Doing so, the ever, if that proposal was rejected would suggest transferring the ecasted values after load sharing Table 3.

ubstations # 24, 25, and 27 are n extra 25 MVA transformer units cities to 100 MVA each will help 2003. Results of the forecasted ne highly growing loads depicted installation of a new 100 MVA well. The resulting load forecast substation (substation #28), are is clear that no overloads are

TABLE 1							
Specificat1	ONS OF A	Lexandr IIC	Installation	GA	GB	GC	
No.	(MVA)	(MVA)	Year	1			
1	50	75	1990	10.817	0.191	0.7757	
2	10	10	1966	479.370	0.0017	0.9812	
3	75	100	1987	621.476	0.1260	1.0213	
4	75	100	1985	398.866	0.1201	0.9908	
5	25	25	1989	16.634	0.8705	0.1952	
6	75	100	1990	57.771	0.8581	0.5410	
7	75	100	1980	275.781	0.1516	0.9927	
8	50	75	1990	20.843	0.2452	0.3240	
9	75	100	1982	272.825	0.1370	0.9883	
10	30	50	1986	304.652	0.0823	0.9969	
11	25	50	1990	48.850	0.2871	0.8944	
12	75	100	1990	39.540	0.3157	0.4920	
13	60	80	1969	135.180	0.2451	0.9954	
14	50	75	1990	26.246	0.2307	0.4606	
15	75	100	1977	8190.16	0.0132	1.0193	
16	75	100	1988	527.84	0.1095	1.0083	
17	75	100	1982	242.054	0.0809	0.9960	
18	75	100	1986	60.918	0.0551	0.8866	
19	75	100	1983	171.514	0.0267	0.9558	
20	30	40	1964	182.654	0.0002	0.9642	
21	25	50	1986	21.165	0.0000	0.2398	
22	25	50	1986	63.120	0.0811	0.9630	
23	25	50	1990	551.280	0.0101	0.9636	
24	25	35	1977	0.068	10.282	1.0475	
25	75	100	1988.	5.406	2.2084	1.0956	
26	25	50	1988	4.247	0.7061	0.1815	
27	25	50	1983	0.540	3.2983	1.0808	

TABLE 2 Forecast Values for Year 1993

TABLE 4 Load Forecast for Year 2003

ipaci IVA) 5.00 0.0 5.0 10 10.730 0.730 11.0 0.0 75 62.172 62.0 57.0 16.0 75 16.63 75 56.38 0.0 54.0 0.0 0.0 0.0 0.0 45.0 18.0 48.0 25.0 75 49.60 19.86 25 20.000 0.0 20.0 75 0.0 32.0 34.467 34.0 23.0 60 38.396 0.0 0.0 22.74 26.576 0.0 27.0 15 75 52.639 0.0 52.0 75 21.795 17.482 17.115 52.0 22.0 16.0 17.0 0.0 75 10.778 0.0 10.0 25 25 21.155 0.0 20.0 10.0 7.0 6.0 9.16 0.0 9.04 0.0 9.19 75 18.68 0.0 18.0 25 0.0 4.0 5.0

Substation No.	Load Forecast (MVA)	Final Overload (MVA)	New RC (MVA)	Losd Forecast After Transfer
3	10.17	0.0	50.0	11.664
2	20.69	0.0	35.0	20.695
3	72.73	2.737	70.0	70.000
4	72.77	0.0	75.0	73.130
5	16.63	0.0	25.0	16.636
6	57.76	0.0	75.0	58.084
7	55.96	0.0	75.0	56.271
8	20.84	0.0	50.0	20.842
9	57.62	0.0	75.0	57.620
10	28.50	0.0	30.0	28.504
11	36.45	0.0	50.0	36.452
12	39.53	0.0	75.0	39.536
13	40.63	0.0	60.0	40.636
14	26.24	0.0	50.0	26.244
15	18.31	0.0	75.0	18.315
16	43.11	0.0	75.0	43.113
17	23.91	0.0	75.0	23.918
18	41.87	0.0	75.0	41.876
19	39.56	0.0	75.0	78.463
20	25.59	0.0	30.0	59.059
21	21.16	0.0	25.0	21.165
22	16.78	0.0	25.0	16.789
23	32.28	0.0	50.0	32.285
24	166.93	66.936	100.0	100.000
25	122.06	22.066	100.0	100.000
26	4.24	0.0	25.0	4.247
27	154.18	54.185	100.0	100,000
28	-	0.0	100.0	70,799

TABLE 3

Substation No.	RC	Load	Overload	New.	Forecast after	
	(MVA)	Forecast	(MVA)	Capacity	load transfer	
		(MVA)	_	(MVA)		
1	50	8.185	0.0	0.0	8.185	
2	10	14.166	4.166	35.0	14.166	
3	75	66.294	0.0	0.0	66,704	
4	75	62.749	0.0	0.0	62.749	
5	25	16.636	0.0	0.0	17.165	
6	75	57.651	0.0	0.0	57.651	
7	75	52.112	0.0	0.0	52,112	
8	50	20.831	0.0	0.0	20.831	
9	75	51,470	0.0	0.0	51,745	
10	30	27.270	0.0	0.0	27.525	
11	25	27.580	2.580	0.0	25,000	
12	75	39.223	0.0	0.0	39.223	
13	60	39.289	0.0	0.0	39.289	
14	50	26.077	0.0	0.0	26.077	
15	75	23.027	0.0	0.0	23,440	
16	75	48.695	0.0	0.0	48.685	
17	75	22.630	0.0	0.0	22.630	
18	75	28,164	0.0	0.0	28.164	
19	75	25.056	0.0	0.0	26.334	
20	30	15.826	0.0	0.0	16.084	
21	25	21.165	0.0	0.0	21,165	
22	25	12.003	0.0	0.0	12,003	
23	25	15.930	0.0	0.0	15.930	
24	25	25.025	0.025	35.0	25.025	
25	75	32.781	0.0	0.0	32,781	
26	25	4.247	0.0	0.0	4.2437	
27	25	18.732	0.0	0.0	18.732	

VI. CONCLUSIONS

An ES that implements an efficient, comprehensive, and interactive load forecasting plans for distribution systems has been developed in this paper. The proposed ES provides an input to long-term planning issues, with the capability of adjusting the individual substation load forecast according to a reliable total load area forecast. It is the authors view point that the best distribution systems planning results would be achieved if an on-line programming "link" is handled by the proposed expert system to combine daily & monthly forecasting programs with the long-term one. Further research is also expected to include the optimal sizing and locations of the newly added substations in the knowledge base of the proposed ES.

VII. REFERENCES

[1] J. E. D. Northcode-Green, "Comparison tests of fourteen distribution load forecasting method, IEEE Trans. power Apparatus and Systems, Vol. AS-103, No. 6, June 1984, . 1190-1197.

[2] H. L. Wills, "Load forecasting for distribution planning-error and impact

on design," IEEE Trans. power Apparatus and Systems, Vol. AS-103, No. 3, March 1984.

[3] H. L. Wills and J. E. D. Northcode-Green. " Spacial electric load forecasting: A tutorial review," proceedings of IEEE, Feb. 1983.

[4] "Research into load forecasting and distribution planning," EPRI report El-1198, Electric power Research Institute, Palo Alto, CA 1979.

[5] J. A. Morris, "Optimization of power line conductor through the use of computerized feeders network program." proceedings of 10th Annual Modeling and Simulation conference, Pittsburgh, April 1979.

[6] H. A. Smolleck and K. C. Kim, " An interactive distribution load forecasting methodology for minicomputer use based upon a Markov type process," IEEE Trans. power Systems, Vol. 3, No. 1, . 52-59, Feb. 1988.

[7] H. L. Wills, B. W. Powella, and D. L. Wall, "Load transfer coupling regression curve fitting for distribution load forecasting," IEEE Trans. power Apparatus and Systems, Vol. AS-103, No. 5, May 1984.

[8] K. D. C. Stoodley, T. Lewis, and C. L. S. Stainton, Applied Statistical techniques, John Wiley & Sons, 1980.

[9] E. Vennard, Management of the Electric Energy Business, 2ed ed., New York : Mc Graw-Hill Book company.

[10] E. Vennard, The Electric power Business, 2nd ed. New York : Mc Graw Hill Book Company, 1970.

[11] R. L. Sullivan, Power System Planning, New York, Mc Graw-Hill Book Company, 1977.

[12] C. Derman, A Guide to Probability Theory and Applications, Holt, Rinehart and Winston Inc., 1973.

[13] "Research into load forecasting and distribution planning", EPRI Report EL-1198, Vol. 1,2,3, Westinghouse Electric Corporation, August 1980.

[14] M. Iosifesca, Finite Markov process and Their Applications, John Wiley & Sons. 1980.

[15] D. L. Isoascn, Markov Chains : Theory and Applications, John Wiley & Sons. 1976.

[16] L. R. Kirk, "Technical study summary, substation planning program SUBLO", El Paso Electric Company, El Paso, Texas, November 2, 1978.

[17] H. A. Smolleck, "A new distribution system load prediction methodology and analytical methods for distribution system planning and operation," Final Report to El Paso Electric Company, 1982.

[18] Springer, Herlinty and Beggs, Mathematics for Management Series, Irwin, 1965.

[19] E. Masud, * An interactive procedure for sizing and timing distribution substations using optimization techniques," IEEE Trans. power Apparatus and Systems, Vol. AS-93, september/October 1974, . 1281-1286.

[20] D. W. Marquardt, "An algorithm for least squares estimation of nonlinear parameters, "Chem. Eng. progr., 55 (1959), No. 6, .65-70

[21] D. marcelli, Expert System programming in Turbo PROLOG, technical Science center, Tarryton, New York, 1989

[22] Egyptian Electric Authority EEA, Egyptian Ministry of Electricity and Energy, The Annual Electrical Statistics, 1990.

[23] S. Rahman and M. Lauby, "Expert systems and their role in power system planning, Proc. EPRI Conf. on ES Applications for Electric Power Industry, Boston, MASS, September 1991.

APPENDIX A

The tie relationship factor between substations i,j is a subjective value and is determined by the system planner. This factor reflects the presence or absence of an available interconnection between the two concerned

substations. The value of T_{ij} is assigned to one of the following values: T_{ij} = 1 for normal situation. A normal situation implies the existence of a direct interconnection between the two substations, no geographical obstacles, no difference in voltage levels, and non of the two substations has a rapidly growing loads.

 $T_{ii} = 3$ for a low possibility of load transfer. This implies that the

interconnection between the two substations is not direct (i.e. if the interconnection asses through a third substation). T_{ii} = 100 for no possibility of load transfer. This implies that the two

substations are not interconnected at all, or there exists geographical obstacles or difference in voltage levels between substations, or load is growing rapidly in one of the two substations feeding areas so that it can not afford any extra transferred load.