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Paiyanoor-603 104, Tamil Nadu, India

Black Out Recovery in Transmission Network Using Greedy Algorithm

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Abstract — A graph theory based methodology called dijkstra's algorithm is used to find the energizing path of power to flow for a given network after a complete blackout is proposed here. Whenever a blackout occurs in the transmission network, the power system operators are under immense pressure to restore the network.The main aim of the power system restoration is to restore as much load as possible & as quickly as possible. After a blackout occurs first all the generators has to be energized and then synchronized. After synchronization of generators only all the loads can be supplied. For energizing the generators a sequential procedure has to be followed. If the sequence used is wrong then it may lead to cascaded outages.The Dijkstra's algorithm helps in finding the sequence to energize the generators based on least impedance path called minimum spanning tree. Newton Raphson based load flow technique is applied to this resultant minimum spanning tree(power flow path). Based on the results (voltage, current and power flow) obtained from the load flow solutions, other constraints of the restoration problem are applied.

Keywords— Graph theory, blackout, minimum spanning tree, load flow solution.

I. INTRODUCTION

Power system is a complex network involving the flow of power, which is generated using various techniques to meet the need of the industries or domestic consumers [1]. A brownout is an intentional drop in voltage in an electrical power supply system used for load reduction in an emergency [7]. A voltage reduction may be an effect of disruption of an electrical grid, or may occasionally be imposed in an effort to reduce load and prevent a blackout [9].

II. LOAD FLOW ANALYSIS

Power flow studies are of great importance in planning & designing the future expansion of power system as well as in determining the best operation of existing systems [2]. The principle information obtained from power flow study is the magnitude & phase angle of voltage at each bus the real & reactive power following in each line [3]. Power flow calculations usually employ iterative techniques such as Newton-Raphson method solves the polar form of power flow equations until ΔP & ΔQ mismatches at all buses fall within specified tolerances [8]. Newton's method is a successive approximation procedure based on initial estimate of the unknown and the use of Taylor's series expansion and the terms are limited to first order approximation [4]. LF Newton is developed for solution of power flow problems by Newton Raphson method [5].

III. GRAPH THEORY

Graph theory is a branch of data structures concerned about how the networks can be encoded & their properties measured [6]. A graph (G) is a set of points called vertices & the lines connecting the points called Edges. The graphs are broadly classified into two typesIt differs from a directed graph as each edge in E is an unordered pair of vertices. If (v,w) is an undirected edge then (v,w) = (w,v). The other classification is weighted & unweighted graphs. Here electrical network is analyzed as an undirected & weighted graph.

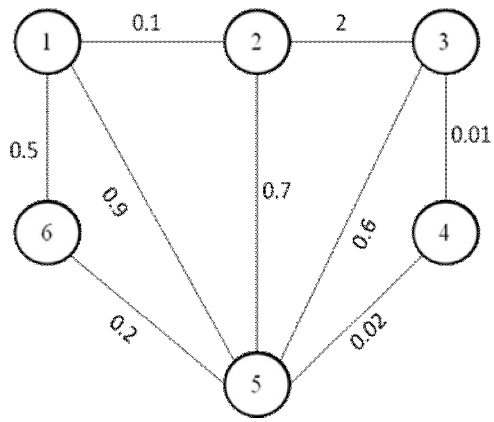

Fig. 1. Example Problem

IV. DIJKSTRA'S ALGORITHM

Dijkstra's algorithm, conceived by Dutch computer scientist Edsger Dijkstra in 1959, is a graph search algorithm that solves the single-source shortest path problem for a graph with nonnegative edge path costs, producing a shortest path tree [6]. It can also be used for finding costs of shortest paths from a single vertex to a single destination vertex by stopping the algorithm once the shortest path to the destination vertex has been determined.

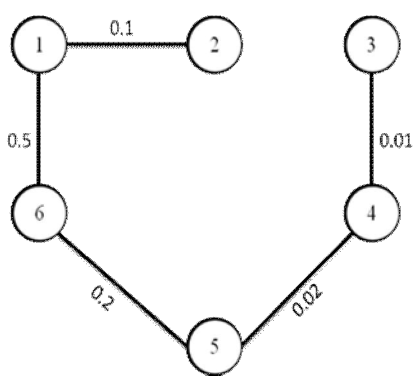

Fig. 2 Minimum Spanning Tree by Dijkstra's Algorithm

By applying Dijkstra's Algorithm we get minimum spanning tree of distance 0.83.

TABLE I. Comparison of Results of Various Algorithm

ALGORITHM	DISTANCE CALCULATED FROM MINIMUMSPANNING TREE
Prim's Algorithm	1.03
Dijkstra's Algorithm	0.83
Kruskal's Algorithm	1.03
Reverse Delete Algorithm	1.03

V. RECOVERY PROCESS

The whole recovery process is divided into 3 stages.

A. Black Start

Due to any critical fault or transient in the network a complete blackout will be occurring.

B. System Reconstruction

The generator (Slack bus) started first & based on the sequence of starting & starting time the generators on the network are started.

C. Load Recovery

Initially the critical loads are fed & later after stabilization of the critical loads all other loads are connected.

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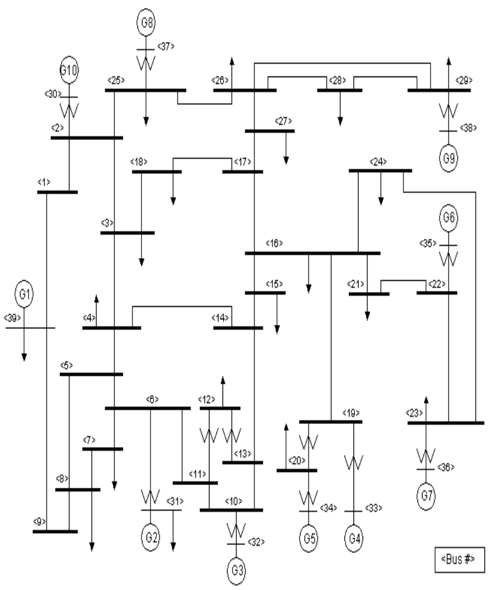

Fig.3. Initial Network

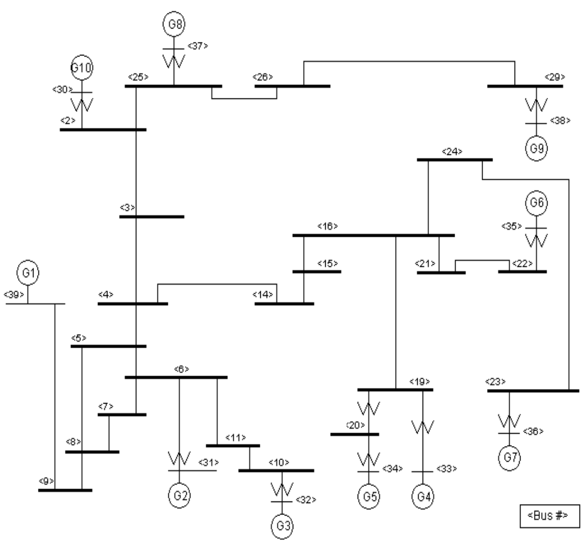

Fig.4. System Reconstruction Stage

TABLE II . Bus Data Of Initial Network

Bus No	Bus Code	Voltage	Load		Generator	
			MW	Mvar	MW	Mvar
1	0	1	0	0	0	0
2	0	1	0	0	0	0
3	0	1	322	2.4	0	0
4	0	1	500	184	0	0
5	0	1	0	0	0	0
6	0	1	0	0	0	0
7	0	1	233.8	84	0	0
8	0	1	522	176	0	0
9	0	1	0	0	0	0
10	0	1	0	0	0	0
11	0	1	0	0	0	0
12	0	1	7.5	88	0	0
13	0	1	0	0	0	0
14	0	1	0	0	0	0
15	0	1	320	153	0	0
16	0	1	329	32.3	0	0
17	0	1	0	0	0	0
18	0	1	158	30	0	0
19	0	1	0	0	0	0
20	0	1	628	103	0	0
21	0	1	274	115	0	0
22	0	1	0	0	0	0
23	0	1	247.5	84.6	0	0
24	0	1	308.6	-92	0	0
25	0	1	224	47.2	0	0
26	0	1	139	17	0	0
27	0	1	281	75.5	0	0
28	0	1	206	27.6	0	0
29	0	1	283.5	26.9	0	0
30	2	1	0	0	250	0
31	1	1	9.2	4.6	0	0
32	2	1	0	0	650	0
33	2	1	0	0	632	0
34	2	1	0	0	508	0
35	2	1	0	0	650	0
36	2	1	0	0	560	0
37	2	1	0	0	540	0

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38	2	1	0	0	830	0
39	2	1	1104	250	1000	0

TABLE III Output of Initial Network

Load		Generation		Injected
MW	***Mvar***	***MW***	***Mvar***	***Mvar***
6097	1409	6145	1445.9	0

Total Line loss	
MW	**Mvar**
48.310	36.862

TABLE IV . Detailed Output Of Initial Network

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Bus no	Voltage	Angle	Load		Generation		Injected
			MW	*Mvar*	*MW*	*Mvar*	*Mvar*
1	1.004	-8.408	0	0	0	0	0
2	0.985	-5.3	0	0	0	0	0
3	0.966	-8.525	322	2.4	0	0	0
4	0.944	-9.657	500	184	0	0	0
5	0.95	-8.525	0	0	0	0	0
6	0.953	-7.782	0	0	0	0	0
7	0.942	-10.22	233	84	0	0	0
8	0.942	-10.77	522	176	0	0	0
9	0.988	-10.47	0	0	0	0	0
10	0.962	-4.966	0	0	0	0	0
11	0.958	-5.922	0	0	0	0	0
12	0.937	-5.876	7.5	88	0	0	0
13	0.957	-5.712	0	0	0	0	0
14	0.951	-7.457	0	0	0	0	0
15	0.947	-7.538	320	153	0	0	0
16	0.961	-7.538	329	32.3	0	0	0
17	0.965	-5.752	0	0	0	0	0
18	0.964	-8.098	158	30	0	0	0
19	0.979	0.195	0	0	0	0	0
20	0.976	-0.81	628	103	0	0	0
21	0.959	-2.97	274	115	0	0	0
22	0.976	2.178	0	0	0	0	0
23	0.973	1.939	247	84.6	0	0	0
24	0.967	-5.612	308	-92	0	0	0
25	0.996	-3.796	224	47.2	0	0	0
26	0.987	-5.072	139	17	0	0	0
27	0.97	-7.291	281	75.5	0	0	0
28	0.989	-1.128	206	27.6	0	0	0
29	0.992	1.96	283	26.9	0	0	0
30	1	-2.668	0	0	250	87.2	0
31	1	0	9.2	4.6	525	227.	0
32	1	2.801	0	0	650	234.	0
33	1	5.394	0	0	632	141.	0
34	1	4.497	0	0	508	133	0
35	1	7.64	0	0	650	195	0
36	1	10.907	0	0	560	133	0
37	1	3.416	0	0	540	336	0
38	1	9.433	0	0	830	65.8	0
39	1	-10.19	110	250	100	190	0

VI RESULTS OF NEWTON-RAPHSON METHOD

--Line--		Power at bus & line flow			--Line loss--	
From	*To*	*MW*	*Mvar*	*MVA*	*MW*	*Mvar*
1		0.000	0.000	0.000		
	2	-125.392	24.820	127.824	0.671	-61.246
	39	125.392	-24.820	127.824	0.158	-71.359
2		0.000	0.000	0.000		
	1	126.063	-86.066	152.640	0.671	-61.246
	3	363.659	94.209	375.664	1.924	-2.131
	25	-239.722	66.443	248.759	4.534	-8.760
	30	-250.000	-74.586	260.889	0.000	12.691
3			-322.000	-2.400	322.009	
	2	-361.736	-96.340	374.345	1.924	-2.131
	4	90.339	85.188	124.170	0.241	-16.229
	18	-50.603	8.752	51.355	0.034	-19.479
4			-500.000	-184.000	532.781	
	3	-90.098	-101.416	135.657	0.241	-16.229
	5	-140.702	-43.228	147.193	0.190	-8.983
	14	-269.200	-39.356	272.062	0.661	-1.741
5		0.000	0.000	0.000		
	4	140.892	34.245	144.995	0.190	-8.983
	6	-457.407	-77.875	463.988	0.476	2.265

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	8	316.514	43.629	319.507	0.911	-0.462
6		0.000	0.000	0.000		
	5	457.883	80.139	464.843	0.476	2.265
	7	420.738	84.670	429.173	1.223	8.594
	11	-362.412	-21.029	363.021	1.014	-0.800
	31	-516.210	-143.780	535.859	0.000	79.029
7			-233.800	-84.000	248.432	
	6	-419.516	-76.076	426.358	1.223	8.594
	8	185.716	-7.924	185.885	0.155	-5.140
8			-522.000	-176.000	550.872	
	5	-315.604	-44.092	318.669	0.911	-0.462
	7	-185.560	2.784	185.581	0.155	-5.140
	9	-20.836	-134.692	136.294	0.371	-29.592
9		0.000	0.000	0.000		
	8	21.207	105.100	107.218	0.371	-29.592
	39	-21.207	-105.100	107.218	0.027	- 117.899
10		0.000	0.000	0.000		
	11	364.020	65.127	369.800	0.593	-0.339
	13	285.980	73.760	295.339	0.379	-2.637
	32	-650.000	-138.887	664.673	0.000	95.486
11		0.000	0.000	0.000		
	6	363.425	20.229	363.988	1.014	-0.800
	10	-363.427	-65.466	369.276	0.593	-0.339
	12	0.001	45.237	45.237	0.036	0.971
12		-7.500	-88.000	88.319		
	11	0.034	-44.266	44.266	0.036	0.971
	13	-7.534	-43.734	44.379	0.036	0.976
13		0.000	0.000	0.000		
	10	-285.601	-76.397	295.642	0.379	-2.637
	14	278.031	31.687	279.830	0.774	-6.998
	12	7.570	44.710	45.347	0.036	0.976
14		0.000	0.000	0.000		
	4	269.861	37.615	272.470	0.661	-1.741
	13	-277.256	-38.685	279.942	0.774	-6.998
	15	7.395	1.070	7.472	0.007	-32.872
15		-320.000	-153.000	354.696		
	14	-7.388	-33.942	34.737	0.007	-32.872
	16	-312.612	-119.058	334.516	1.106	-4.022
16		-329.000	-32.300	330.582		
	15	313.718	115.036	334.144	1.106	-4.022
	17	230.494	-60.279	238.246	0.425	-7.052
	19	-502.095	-35.931	503.379	4.372	24.659

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	21	-328.465	35.266	330.353	0.953	-7.401
	24	-42.651	-86.392	96.347	0.028	-5.761
17		0.000	0.000	0.000		
	16	-230.070	53.226	236.147	0.425	-7.052
	18	208.966	-6.651	209.072	0.328	-8.420
	27	21.104	-46.575	51.134	0.020	-29.845
18		-158.000	-30.000	160.823		
	3	50.638	-28.231	57.976	0.034	-19.479
	17	-208.638	-1.769	208.645	0.328	-8.420
19		0.000	0.000	0.000		
	16	506.468	60.590	510.079	4.372	24.659
	33	-629.063	-82.369	634.433	2.937	59.579
	20	122.595	21.779	124.515	0.113	2.230
20		-628.000	-103.000	636.391		
	34	-505.518	-83.451	512.360	2.482	49.640
	19	-122.482	-19.549	124.032	0.113	2.230
21		-274.000	-115.000	297.155		
	16	329.418	-42.667	332.170	0.953	-7.401
	22	-603.418	-72.333	607.738	3.202	32.014
22		0.000	0.000	0.000		
	21	606.620	104.347	615.529	3.202	32.014
	23	43.380	25.408	50.273	0.019	-17.229
	35	-650.000	-129.755	662.825	0.000	65.891
23		-247.500	-84.600	261.560		
	22	-43.361	-42.636	60.811	0.019	-17.229
	24	354.204	1.205	354.206	2.924	12.573
	36	-558.343	-43.168	560.009	1.657	90.132
24		-308.600	92.000	322.022		
	16	42.680	80.631	91.230	0.028	-5.761
	23	-351.280	11.369	351.464	2.924	12.573
25		-224.000	-47.200	228.919		
	2	244.256	-75.204	255.571	4.534	-8.760
	26	69.987	-3.567	70.078	0.173	-48.698
	37	-538.242	31.571	539.168	1.758	67.958
26		-139.000	-17.000	140.036		
	25	-69.813	-45.131	83.131	0.173	-48.698
	27	261.018	80.848	273.252	1.102	-11.383
	28	-140.507	-24.706	142.663	0.879	-66.490
	29	-189.697	-28.011	191.754	2.134	-77.314
27		-281.000	-75.500	290.966		
	17	-21.084	16.731	26.915	0.020	-29.845
	26	-259.916	-92.231	275.795	1.102	-11.383
28		-206.000	-27.600	207.841		

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	26	141.386	-41.784	147.431	0.879	-66.490
	29	-347.386	14.184	347.676	1.737	-5.691
29		-283.500	-26.900	284.773		
	26	191.831	-49.304	198.066	2.134	-77.314
	28	349.123	-19.874	349.688	1.737	-5.691
	38	-824.454	42.278	825.537	5.546	108.145
30		250.000	87.276	264.796		
	2	250.000	87.277	264.797	0.000	12.691
Total loss			**48.310**			**36.862**

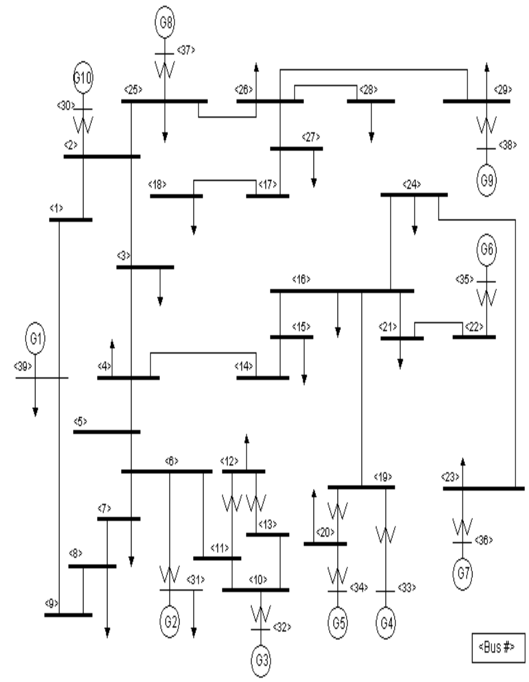

Fig.5. Load Recovery Stage

VI. CONCLUSION

This paper presents the use of Dijkstra's Algorithm for service restoration plan after a complete blackoutBy application of graph theory the process had been made simple and user friendly. In order to demonstrate the efficiency of dijkstra's algorithm it has been applied to IEEE 10 Generator 39 Bus System. We carry out three stages of recovery process by using dijkstra's algorithm. Newton-Raphson method is used to carry out load flow analysis. The simulation results show that Newton-Raphson method is effective and promising. It has been found that by application of dijkstra's algorithm the transmission losses can be reduced to significant extent.The advantages are (1) solution procedure leads to the optimum solution & (2) avoid combinational explosion of the number of the number of configurations to be tested. This it is believed that the results from Dijkstra's algorithm in power system restoration results in better plan, so it can be considered for real time application.Since the simulation implementation is done only for 39 bus system it can be extended to networks with more number of buses.

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