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An Investigation into 9-Busbar and IEEE Modified 118-Busbar Systems for the Sake of Miniaturization of Power System Model

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Abstract: Many efforts have been made for optimization of generation and transmission network. The present paper aims at studying 9-busbar and IEEE modified 118-busbar systems for the sake of miniaturization of power system model. Though network reduction results into a simple but precise model, lack of proper current limiting can constrain its applications. This problem can be solved through reformation of transmission network including split bus and removing lines. To this end, MATLAB software was used. The obtained results revealed that using modified busbar systems for the sake of optimization of power systems is to 80% significant; and system miniaturization remarkably reduces the computational costs.

INTRODUCTION

A common method for reducing the high computational costs of a power system in large scale is network reduction. Reduced system should precisely present the original system, so that, it can be analyzed. The costs of analysis using reduced model should be remarkably less than the costs of analyzing the original system. Many reduction model methods focus on systems predictable in terms of loads. In many cases, they propose a precise description of the systems being studied. There are various types of reduction method all considering the features of the original system that are also found in the reduced model (NPCC., 1997). Due to economic growth and increase in global population particularly in urban areas the demand for electricity is rapidly increasing. In order to provide the sufficient electrical energy, the network should be expanded through adding to the number of power stations, substations and transmission lines. Problems related to reformation of the network can be solved faster in the small systems, compared to big ones. Also, this method can reduce the time needed for the computation (ISO-NE, 2007).

Optimal Power Flow (OPF): Minimizing a network to a smaller system remarkably reduces the computational costs. It is not obvious that which busbars should be defined. Therefore, if the original system is used for studying the OPF, the power and injection features may be remarkably different. In studying OPF, usually congestion has an impact on the costs of the system. Congestion has a vital role in OPF and planning studies. Congestion happens where the line current is more than the limit. Determining the current limiting is of great importance (Fisher *et al*., 2008).

Therefore, determining the proper current limiting is crucial for the line assembly. The aim of network reduction is planning the studies. So, unpredicted congestions may happen to the sets. Some of the solutions of planning studies using the model may not be practical. Studies should be done considering different loads. The extant paper studies 9-busbar and IEEE modified 118-busbar systems for the sake of miniaturization of power system model (Hedman *et al*., 2009).

Miniaturization of power system model for estimating short-circuit currents: Due to economic growth and increase in global population particularly in urban areas the demand for electricity is rapidly increasing. In order to provide the sufficient electrical energy, the network should be expanded through adding to the number of power stations, substations and transmission lines. Therefore, transmission systems will be more complicated. One of the most important problems is producing short-circuit current. This problem has been studied and the results revealed that this problem can be solved through reformation of transmission network including split bus and removing lines (Hedman *et al*., 2010).

Miniaturization of power system model: According to the previous section, bus impedance matrix Z_{bus} is used for calculating short-circuit currents. The size of Z_{bus} equals to the number of the buses in a system. Therefore, the computational time of short-circuit currents depends on the size of Z_{bus}. In order to supervise short-circuit currents just in a small area of the entire transmission system; network miniaturization remarkably reduces the computational time. In order to reduce the network to the desired secondary area which is connected to the huge power system, the transmission network is divided into three parts. The first system is the internal system that is the boundary of the regulatory region of the short-circuit currents. The second system is the external system that is in the external area and is connected to the internal system through power-line communication (Jiratawaree and Chitusaney, 2010).

MATERIALS AND METHODS

Congestion depends on the limits of the current. For example, the excessive current of flow congestion is more than the limits of line current. Therefore, the second factor is the product of sensitivity of binding limits and the hidden price of the margin of the bus. It means:

$$\rho_{congestion} = \left(\frac{\partial flow_{congestion}}{\partial P_d}\right)^T \alpha = E^T \alpha \quad (1)$$

The impacts of congestion will be different based on the electrical distance of the buses from the line with high congestion. The impact can be positive or negative. For example, considering the congestion, higher or lower LMP depends on X. The system congestion is divided into two areas. One of them is being under the positive influence of LMPs and the other is being under the negative influence of LMPs while the line has high congestion. Disregarding the dissipation, the power injected for the end of a line is equal to the one of the other end. There is a shortage of the power in the area where the demand is high. Congestion causes high LMP compared to other areas. The injection area is called SRA because the sum total of the loads is less compared to the generation.

In power system modeling, AC power flow is the most complete and precise method. Therefore, DC power flow is widely used for the approximate power of the system. DC power flow is mostly the simplest power flow by the combination of some approximations. DC power flow reduces the problems of power flow for a set of linear equations. As a linear system, DC model has good features including being linear and having a wonderful situation. If DC model is used for analyzing the transmission factor, there will be a simple relation between PTDFs and ISFs (Triyachote and Chitusaney, 2010).

RESULTS AND DISCUSSION

If the areas are proposed, a simple but precise model of the reduced system will be obtained. In order to define the areas, the internalbusbars of the area should have similar features. Therefore, the area is a set of busbars in which LMP or PTDF matrix change to the same amount (Fig. 1-4 and Table 1).

Table 1: Busbar arrangement based on PTDF matrix

Busbars	The value of PTDF matrix line-2	Busbar arrangement
1	0	1
2	1	2
3	0	1
4	0	1
5	0	1
6	0	1
7	0	1
8	0	1
9	0	1

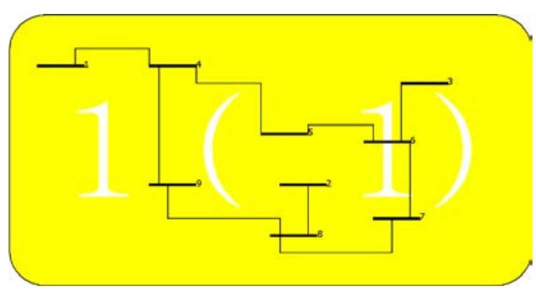

Fig. 1: IEEE modified 9-busbar system

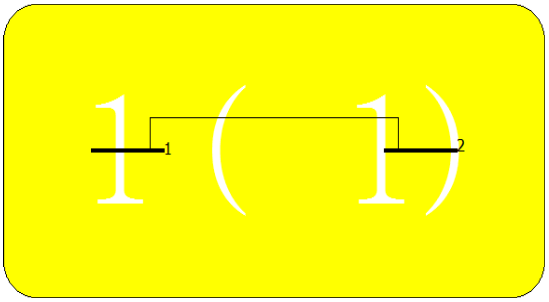

Fig. 2: Reduction of IEEE 9-busbar system based on busbar arrangement in Table 1

IEEE 118-busbar system is shown in Fig. 5 and 6. The limits of the current of some lines change in order to develop congestion features.

AC power flow studies have been done on the features of different loads on the original and reduced networks, in order to compare the obtained results. Different loads have been simulated in order to find the features of different congestions. The results of the stimulations are available in Table 2 and 3. The item mentioned in Table 2 is condensed and the one in Table 3-5 includes a congestion line (37-38).

According to the obtained results, LMP and the generation sample of reduced networks are approximately

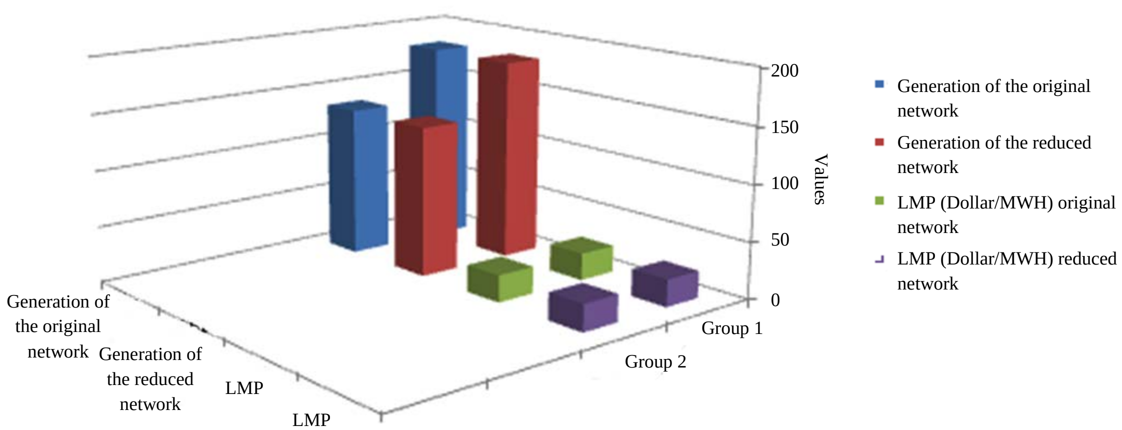

Fig. 3: Comparison of generation amounts and LMPs of the original network and the reduced network regardless of the congestion line

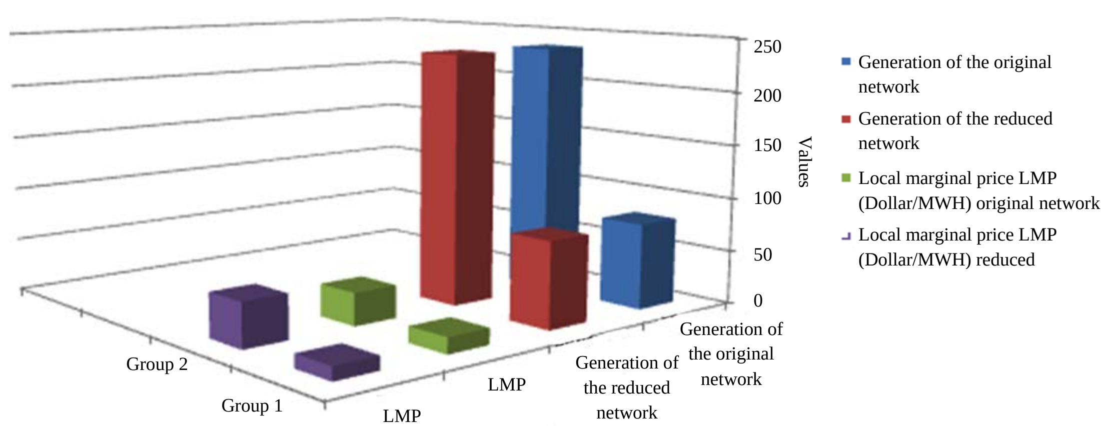

Fig. 4: Comparison of generation amounts and LMPs of the original network and the reduced network regarding the congestion line 8-2

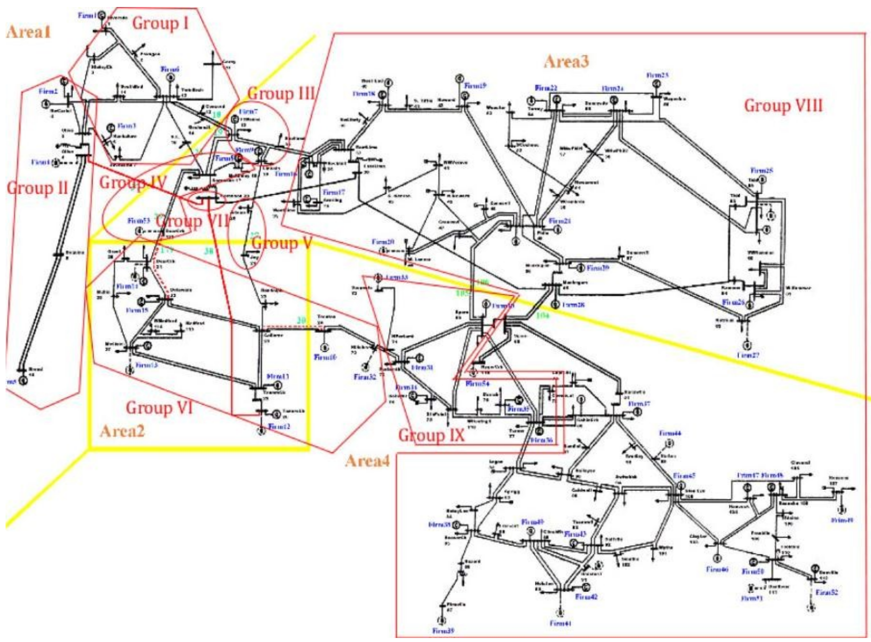

Fig. 5: IEEE modified 118-busbar system. Boundary lines (37-38) can be condensed

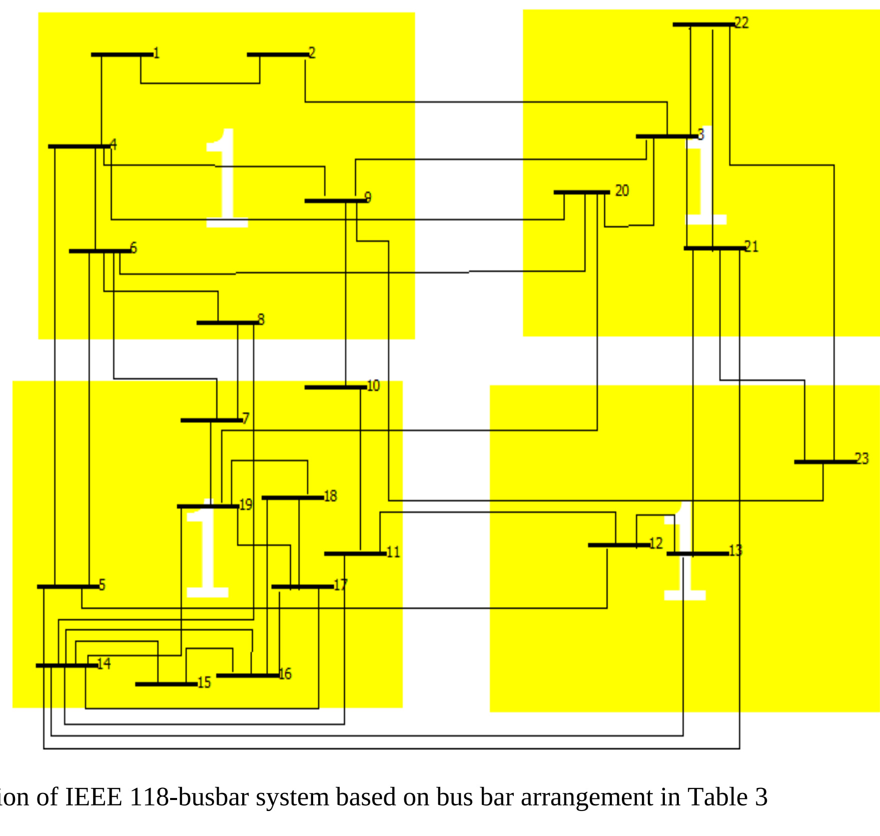

Fig. 6: Reduction of IEEE 118-busbar system based on bus bar arrangement in Table 3

the same as the original network. Therefore, the results of power flow of the reduced network are useful for estimation of the original network.

There are three factors in LMP: marginal price of power system, the impact of congestion and the dissipation-related costs. Usually, the margin is the last

Table 2: Determination of reactance of reduced 9-busbar network

Branch	Reactance of reduced network
1-2	020625

Table 3: Busbar arrangement

Groups	Busbars
1	1, 6, 81, 86, 87, 93
2	2, 14, 55, 84, 94
3	3, 7
4	4, 59, 90, 92, 101, 102
5	5, 15, 68, 89, 99, 100, 116
6	8, 9, 28, 29, 72
7	10, 27, 65, 114, 115
8	11, 48, 58, 83, 96, 97
9	12, 49, 54, 56, 74, 98
10	13
11	16, 88, 85, 70
12	17, 23, 24, 113
13	18
14	19, 63, 71, 91, 106
15	20, 60, 62, 67, 103, 104, 105
16	21, 61, 64, 66, 73, 107, 108, 109, 110, 112
17	22, 111
18	25
19	26
20	30
21	33, 51, 53, 75, 77
22	34, 35, 36
23	37, 39
24	38
25	42, 46, 47, 69
26	43
27	44
28	45
29	50, 76, 95
30	52, 78, 79, 82, 118
31	57, 80, 117

part. In the first time, LMP is uniformly affected; therefore, does not propose useful data for defining the area. So, this study discussed the impact of congestion on LMP. The amounts mentioned in the second column of Table 1 tend to identify unique groups and the amounts of the third column determine the membership data of each busbar in the group (Fig. 7 and 8).

The system congestion is divided into two areas. One of them is being under the positive influence of LMPs and the other is being under the negative influence of LMPs while the line has high congestion. Disregarding the dissipation, the power injected for the end of a line is equal to the one of the other end. There is a shortage of the power in the area where the demand is high. Congestion causes high LMP compared to other areas. The injection area is called SRA because the sum total of the loads is less compared to the generation. Busbar arrangement is displayed in Fig. 1.

The result of the proposed method is a way to arrange the busbars in order maintain network congestion features. So, unpredicted congestions may happen in a part of the network. The aim of network

Table 4: Without congestion line

	LMP (Dollar/MWH)		Generation (MWH)	
Groups	Original	Reduced	Original	Reduced
1	532320	552477	125222	147252
2	532718	552588	99299	70285
3	532366	552538	-	-
4	512924	552426	338	318202
5	512830	552359	515234	487279
6	512599	552271	109289	150236
7	502672	552224	338241	422274
8	532531	552703	-	-
9	532318	552576	475286	400239
10	552396	552824	-	-
11	532272	552419	81202	140217
12	512294	552078	101292	137208
13	512444	552165	52202	68293
14	512422	552277	125219	138288
15	522518	552244	20623	258222
16	522746	552201	536232	524293
17	522474	552069	42278	46241
18	502141	542678	103261	119221
19	512996	542733	113275	131272
20	512172	552138	-	-
21	502317	552725	100200	71248
22	472487	552399	243214	209298
23	462888	552370	-	-
24	502619	552315	-	-
25	562329	552451	290289	247203
26	532981	552799	-	-
27	622117	562021	-	-
28	642316	552993	-	-
29	622326	552742	97207	71255
30	642864	552815	-	-
31	622889	552601	171216	147216

Table 5: When the 37-38 line is condensed

	LMP (Dollar/MWH)		Generation (MWH)	
Groups	Original	Reduced	Original	Reduced
1	592519	572778	185223	168289
2	612405	592263	9727	87256
3	602319	582467	-	-
4	572598	562596	354221	337254
5	562634	552856	515246	498248
6	492397	492528	86205	96228
7	482464	492823	266202	330205
8	652418	602699	-	-
9	622488	592899	50928	471214
10	912925	602625	-	-
11	582451	572686	16921	160278
12	472033	472549	64265	68263
13	512466	512849	52212	53286
14	552023	552744	140213	143213
15	542432	542596	24129	248247
16	532336	542034	476279	495247
17	502701	522296	40229	42274
18	422200	432077	76231	79233
19	392809	392981	75212	75277
20	342237	322959	-	-
21	66241	632133	100200	100200
22	7329894	1062828	300	300200
23	752303	1122920	-	-
24	-102826	-102278	-	-
25	702850	642861	356202	323273
26	772709	962717	-	-
27	782559	782870	-	-
28	762431	712658	-	-
29	642469	612004	100200	95247
30	672645	622786	-	-
31	632854	602345	181201	166277

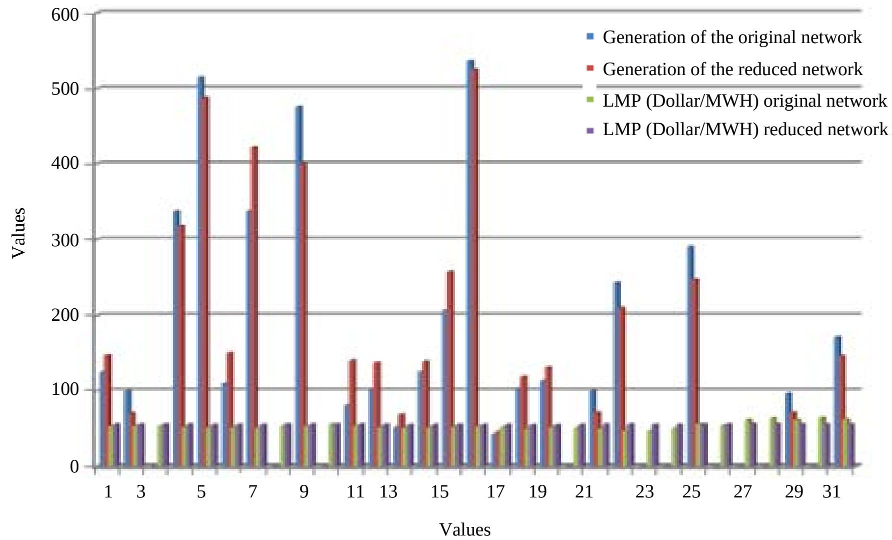

Fig. 7: Without congestion line

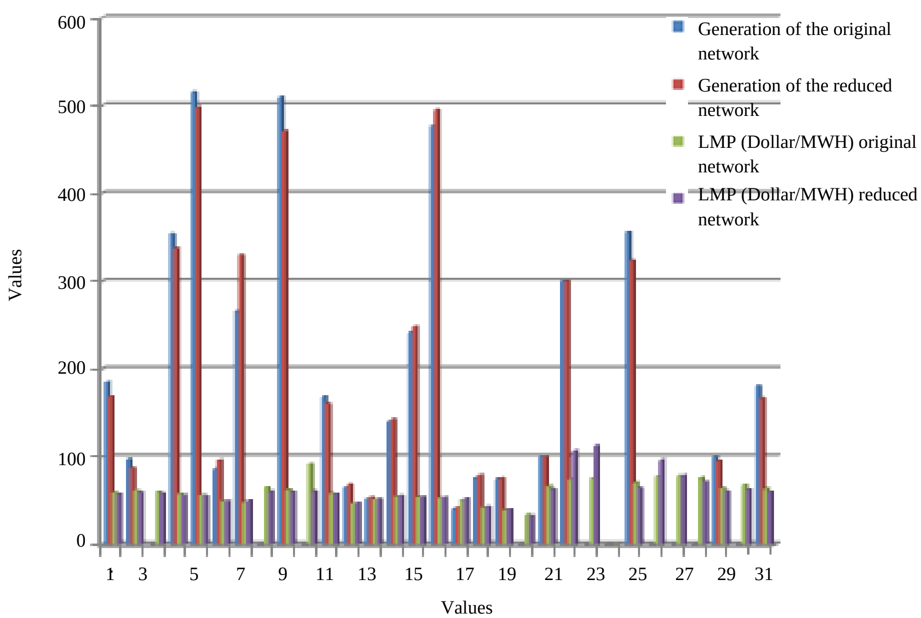

Fig. 8: When the 37-38 line is condensed

reduction is planning the studies. If the condensed lines completely change the features of the congestion, this algorithm cannot display the features of the proper congestion. Therefore, it is crucial to determine the lines that may be condensed or are already condensed. At the time of peak consumption line 37-38 can be condensed. The original network, using the amounts of LMP resulted into the 23 groups mentioned in Table 3 and the reduced network was developed.

CONCLUSION

In order to expand efficient algorithms for the optimization of generation and transmission network, the extant paper studied 9-busbar and IEEE modified 118-busbar systems for the sake of miniaturization of power system model. The obtained results displayed that using modified busbar systems for the sake of optimization of power systems is to 80% significant and system miniaturization remarkably reduces the computational costs.

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