Network for Research and Development in Africa
International Journal of Knowledge and Dynamic Systems
ISSN: 2384-5368, Volume 13, Issue 6
PP 93-102 (December, 2023)
DOI: 6732-1453-71-1369
arcnjournals@gmail.com
https://arcnjournals.org

Systematic Numerical Load Flow Analysis to Assess Power System Security in Electrical Operation System

Babagana D. Maikale, Musa M. Gujja, Tijjani Bura Ngajia, Mohammad Goni Mustapha
Department of Electrical and Electronics Engineering, Ramat Polytechnic Maiduguri, Borno State

***Abstract**: This study report and Systematic Numerical Load Flow Analysis to Assess Power System Security in Electrical Operation System and the purpose of security assessment is to provide information to the system operators about the secure and insecure nature of the operating states in the event of any contingency, so that proper control/corrective action can be initiated within the safe time limit. Power system security must be concerning all the time to ensure that the system always operate in a good condition. To make sure that the system operates in a good condition, security assessment must be done on the current system. Thus, this project performed power system security and assessment on 14 buses, the work is done to identify faulty buses and lines in order to take prompt action to sure that there is no problem occurs at the transmission line such as power overload and no voltage violation occurs at bus when one or two of the transmission lines are eliminated. If there is a power overload in the system, contingency analysis must be done on the system to secure back the system. To secure back the system, transmission line of the system must be rank first according to its severity level by using appropriate assessment method. (N-1) contingency analysis has been used to assess the security level of the test system. In this project, Matlab software is used for the analysis and IEEE 14-bus system is used as the test system. This project only focusses on the transmission line capacity in the system and the voltage changes at the bus. The system was tested 4 different conditions, these include normal conditions, 5% Overloaded, 10% overloaded, 15% overloaded, 20% overloaded. The project was successfully done with all contingencies analysed. Hence, this project has conducted security assessment on 14 bus power system and will provide reliable data for future power system assessment and operation.*

***Keywords:** Systematic Numerical, Load Flow Analysis, Power System Security, Electrical Operation System.*

Introduction

Security assessment is concerned with factors related to the insecurity situation. Where viable approach to accurately determine specific is challenging[1]. However, such challenge could be overcome by adopting contingency selection and ranking based accurate checking of overload and overvoltage via load flow calculation of the power system in post-contingency condition. Power system security is very important to determine the continuous electrical supply[2]. Therefore, we must find ways in determining the level of power system security. Load flow analysis is one of the method that can be used in determining the level of power system security[3]. But, load flow analysis method is also an iterative method, which is time consuming in determining the level of the power system security. Because of the technologies in computer is very advanced, many software that can be used in determining the level of power system security[4]. In an event the security challenge is imminent, in cooperation of virtual power plant is a viable solution. The virtual power plant is incorporation of renewable energy to grid system to compensate or supplement the in case of blackout or under voltage supply. It is also interesting to note that excess power supply could sale back to the grid[5]. This is important since there is a need to calculate the security level of system quickly. One of the software that can be used in determining the security level of power system is MATLAB and RETScreen. MATLAB can be used to do the mathematical works quickly than using conventional method[6]. This also, will make the results of the security level of power system is more accurate. One way to determine the level of power system security is by doing line outage contingency analysis for the system[7]. By using this method, the transmission line can be ranked and the most dangerous line can be determined[8, 9]. So, improvement of the system can be achieved by using some method such as introducing new back up line[10, 11]. This study helps in analysing security of power system size optimization techniques considering the uncertainty of the solar irradiance. The use of DE algorithm helps in appropriate sizing of PV system and also help in reducing computational and convergence time[12, 13]. paper presented economically implementation of the stand-alone PV system.

Methods

This section outlines the methods and procedures that is adopted to implement the set objectives of the research. This focus on Hadi Saat algorithms adopted and implemented in MATLAB programming environment. It cover the details of 14 Bus system analysis.

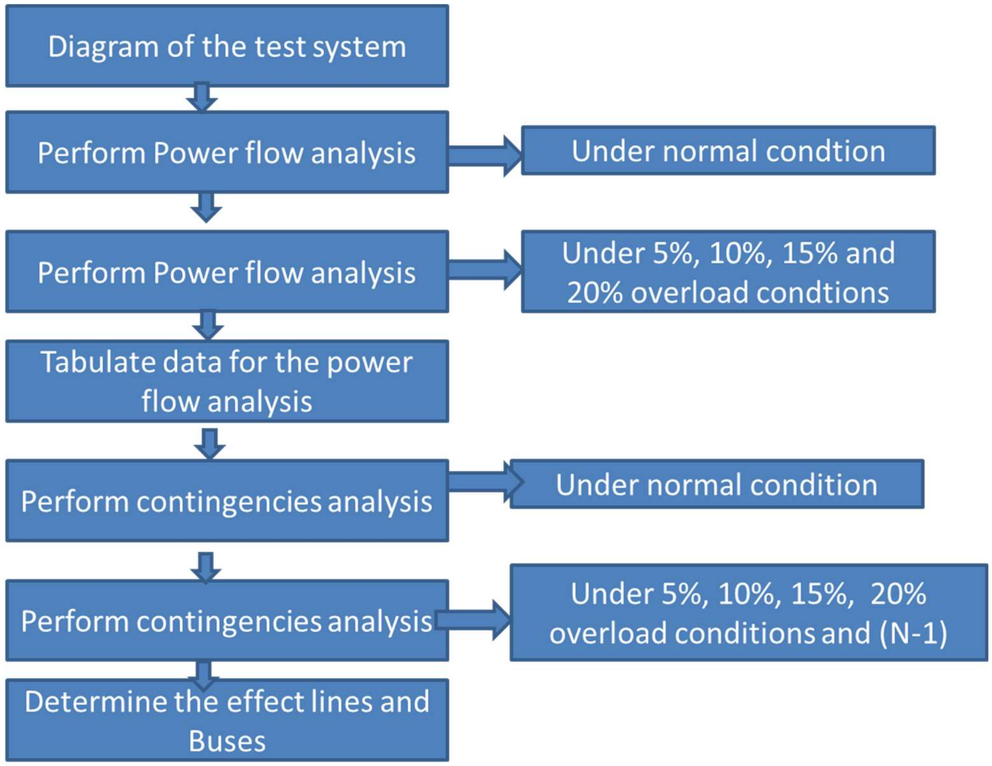

Figure 1 Flow chart for the power security assessment process.

In this paper, the factors that are assessed is only bus voltages. Static security assessment can be done by using Load Flow Analysis. There are many method that can be done to solve Load Flow Analysis such as Gauss-Seidel method, Newton Raphson method, and also Fast Decoupled method. The method that are chosen in this project is Newton-Raphson method. This is mainly because of the advantages of the Newton-Raphson method itself that is the number of iteration does not depend on the system size. Therefore, the iteration in Newton-Raphson method is still less than another method even it is applied to larger power system network. The type of violations that will be consider in this project is only low voltage violations. This type of violation occurs at buses when the voltage at the bus is not satisfy the operating range of voltage. In this project, the operating range for voltage is set to be 0.95-1.05 p.u. The bus is considered insecure when the voltage at the bus is below 0.95, which can be called as under voltage. When the voltage at the bus higher than 1.05, it is also consider as insecure and is called over voltage. There are many steps that are taken in order to complete this project. Knowledge on each of the steps that had been taken is important to make sure the results are correct. The flowchart of the process to do the static security assessment is as shown in Figure 1 above.

Results and Discussions

The study adopted the IEEE 14-bus standard structure system where the system to show the practicability of the modified algorithm from Hadi Saadat algorisms. To assess the power system, power security contingency ranking and analysis using MATLAB. The IEEE 14-bus system is sown in Figure 1. Bus 1 is the swing bus, bus 2, 3, 6 & 8 are PV buses, and loads are connected at buses 4, 5, 7,9,10,11,12,13, &14 with 5 generators. In the analysis, based IEEE 14-buses power test system the system performance index were determined where the performance for voltage (voltage Index), PI_V index and MVA Performance Index, PI_{MVA}. Voltage Performance Index, PI_V were determined and the violation and possible bus and line with such violations were that occur were identified at all the bus and line in the system during (N-1) line outage contingencies process. While MVA Performance Index, PI_{MVA} describe the MVA violation that occur in all line in the system during (N-1) line outage contingencies occur. The load in the system also is increased by 10% and 20% to add more stress to the system. Bus data for all three types of load and line data are tabulated in appendix. At the end of the analysis, PI_V and PI_{MVA} were combined to get the overall violation that occur in the system thus all the transmission line in the system can be ranking based on its severity level. Load flow analysis criteria , the load flow analysis was conducted based on criteria, where they were violation identified based on as it occurs in the system is check by checking the bus voltage of each bus after occurrence of contingencies. The violation occur if the bus voltage is not in the range of 0.95-1.05 per unit. The MVA violation also was checked by calculating the percentage of the line flow, which exceed the rating MVA for each line.

As mentioned above, the analysis of each bus was conducted with conditions and criteria, the comparison during the analysis, the power system under normal condition were evaluated, this will serve as the results benchmark so that the system could be tested under different conditions. By using Newton-Raphson Load Flow Analysis, the voltage at the bus and power flow in the line were determine. To do this, the system voltage and power was evaluated for system in normal condition with the system subjected to deference load conditions were determined. These include 5%, 10%, 15% and 20% overload.

Table 1: Bus power flow analysis flow analysis during normal conditions

Bus no.	**p.u**	**δ**	**P (MW)**	**Q (MVar)**
1	1.040	0	277.430	17.911
2	1.043	0	18.300	16.832
3	1.005	-8.663	-1.400	-1.300
4	0.980	-13.635	-5.650	-2.600
5	0.980	-10.800	-94.200	16.747
6	0.950	-21.701	-44.33	14.22
7	1.004	-18.605	-22.800	-10.900
8	1.010	-21.594	-30.000	4.369
9	1.017	-18.950	0	0
10	1.022	-19.753	-5.800	-2.000
11	1.040	-21.083	0	16.108
12	0.936	-28.444	-83.000	-7.000
13	1.020	-24.122	0	18.891
14	1.011	-21.664	-6.200	-1.600

From the results in Table 1, it can be seen that the no violation at the normal condition, which in the range of specified voltage, which is from 0.95 p.u to 1.05 p.u is bus 6, which is 0.911 p.u.
It is interested to note that even when the load is increase by 5% from normal load and no line is out, all the other bus voltage is in the range of voltage specified except for bus 6 below the criteria of 0.95 p.u as shown in table 4.2. It also can be seen that most of the bus voltage remain same expect the power some case from the bus voltage in normal load condition.

Table 2: Bus power flow analysis for power analysis during 5% overload

Bus no.	p.u	**δ**	**P (MW)**	**Q (MVar)**
1	1.010	0.000	291.037	15.218
2	1.023	-5.732	16.13	35.19
3	1.000	-9.796	-2.64	-1.32
4	0.972	-13.098	-8.42	-1.76
5	0.970	-13.249	-103.62	10.695
6	0.911	-24.394	52.2	20.33
7	0.999	-20.918	-25.08	-11.9
8	1.010	-24.223	-33	7.347
9	1.034	-21.324	0	0
10	1.019	-22.233	-6.38	-2.2
11	1.040	-23.750	0	19.529
12	0.924	-31.974	-91.3	-7.7
13	1.020	-27.246	0	26.89
14	1.008	-24.418	-6.82	-1.76

Table 3, show the system results with 10% overloaded, the bus voltages are within the p.u criteria except bus six, this result similar to the one in the in table 4.2 for the load condition of 5% overload, it indicate overload of 5% and 10%, the system able to maintain all buses except but 6.

Table 3: Bus power flow analysis for power analysis during 15% overload

Bus no.	p.u	**δ**	**P (MW)**	**Q (MVar)**
1	1.050	0.000	325.780	32.374
2	1.013	-6.370	13.96	25.005
3	0.989	-10.942	-2.88	-1.44
4	0.961	-14.700	-9.18	-1.92
5	0.960	-14.872	-113.04	20.441

6	0.911	-24.394	52.2	20.33
7	0.992	-23.479	-27.36	13.08
8	1.010	-27.109	-36	11.464
9	1.008	-23.968	0	0
10	1.015	-25.023	-6.96	-2.4
11	1.040	-26.809	0	26.799
12	0.950	-35.919	-99.6	-8.4
13	1.010	-30.576	0	29.587
14	0.999	-27.411	-7.44	-1.92

Likewise, from the results in table 4.4, it can be seen that bus 6 and additional bus are affected which not in the range of specified voltage, which is from 0.95 p.u to 1.05 p.u is also bus 12, which is 0.902 p.u. So, when the load is increase by 15% from normal load and no line is out, all the other bus voltage is in the range of voltage specified except for bus 12 and bus 6.

Table 4: Bus power flow analysis for power analysis during 15% overload

Bus no.	**|V|**	**δ**	**P (MW)**	**Q (MVar)**
1	1.050	0.000	325.780	32.374
2	1.013	-6.370	13.96	25.005
3	0.989	-10.942	-2.88	-1.44
4	0.961	-14.700	-9.18	-1.92
5	0.960	-14.872	-113.04	20.441
6	0.901	-27.373	0	0
7	0.992	-23.479	-27.36	13.08
8	1.010	-27.109	-36	11.464
9	1.008	-23.968	0	0
10	1.015	-25.023	-6.96	-2.4
11	1.040	-26.809	0	26.799
12	0.902	-35.919	-99.6	-8.4
13	1.010	-30.576	0	29.587
14	0.999	-27.411	-7.44	-1.92

Table 5: Bus power flow analysis for power analysis during 20% overload

Bus no.	|V|	δ	P (MW)	Q (MVar)
1	1.050	0.000	325.780	32.374
2	1.013	-6.370	13.96	25.005
3	0.989	-10.942	-2.88	-1.44
4	0.961	-14.700	-9.18	-1.92
5	0.960	-14.872	-113.04	20.441
6	0.900	-27.373	0	0
7	0.902	-23.479	-27.36	13.08
8	1.010	-27.109	-36	11.464
9	1.08	-23.968	0	0
10	1.015	-25.023	-6.96	-2.4
11	1.040	-26.809	0	26.799
12	0.902	-35.919	-99.6	-8.4
13	1.150	-30.576	0	29.587
14	0.999	-27.411	-7.44	-1.92

From table 5, as the load increase by 20% several buses are out, these includes 6, 7, 9, 12, and Power flow analysis From the results in Table 6, for load increase by 20%, the line, which has the most power flow in it is also line 1-2, which is 158.603 MW. The real power flow in this line is 160.603 MVA and the reactive power flow in this line is -0.149 MVar. Thus, this section dedicated to explaining the discussion power flow from normal condition to 5%, 10%, 15% and 20%. It found that the power flow in the line increase when there is increase in the load in the test system. Besides that, the lost in each line also increase when there is increase in the load.

Table 6: Under Normal condition

S.no	Line to Line	Loading	P (MW)	Q (MVar)	S (MVA)
1	L1(2-5)	1.408	158.603	-0.149	160.603
2	L2(6-12)	1.3614	98.902	16.049	100.196
3	L3(12-13)	1.4286	33.950	0.132	33.950
4	L4(6-13)	1.0457	67.993	4.271	68.127
5	L5 (6-11)	1.2666	70.533	4.479	70.675
6	L6(11-10)	1.3191	31.029	1.244	100.054
7	L7(9-10)	1.4876	6.193	-1.814	6.453
8	L8(9-14)	1.6338	58.391	2.902	58.463
9	L9(14-13)	1.3615	23.560	0.490	23.565
10	L9(7-9)	1.0237	73.728	16.372	75.524

11	L11(1-2)	1.3375	-7.204	-2.949	7.785
12	L12(3-2)	1.3536	51.231	14.724	53.304
13	L13 (3-4)	1.4387	29.702	-8.402	30.867
14	L14(1-5)	1.3964	30.000	-2.782	30.129
15	L15 (5-4)	1.2946	5.591	-12.329	13.538
16	L16 (2-5)	1.3452	13.316	-10.433	16.917
17	L17(5-6)	1.456	15.835	-4.624	16.496
18	L18(4-9)	1.3755	7.429	-12.666	14.684
19	L19 (4-7)	1.3699	-35.077	0.840	35.087
20	L20 (8-7)	1.1686	-9.075	7.393	11.705

The table 7 show the system power flow of the system with 5% overloaded, it can be observe that that the power at 241.029 MW, 233.054 MVA with reactive power of 7.244 MVar. The result is corresponding the voltage flow analysis where the bus six was violating the system.

Table 7: Under 5% overloaded

S.no	Line out stage	Maximum loading	**P (MW)**	**Q (MVar)**	**S (MVA)**
1	L1(2-6)	1.408	241.029	7.244	233.054
2	L2(6-12)	1.3614	98.902	16.049	100.196
3	L3(12-13)	1.4286	43.950	0.132	33.950
4	L4(6-13)	1.0457	57.993	5.271	68.127
5	L5 (6-11)	1.2666	75.533	4.479	70.675
6	L6(11-10)	1.3191	41.029	7.244	33.054
7	L7(9-10)	1.4876	55.193	-3.814	6.453
8	L8(9-14)	1.6338	48.391	2.902	58.463
9	L9(14-13)	1.3615	23.560	0.490	23.565
10	L9(7-9)	1.0237	73.728	16.372	75.524
11	L11(1-2)	1.3375	-7.204	-2.949	7.785
12	L12(3-2)	1.3536	51.231	14.724	53.304
13	L13 (3-4)	1.4387	29.702	-8.402	30.867
14	L14(1-5)	1.3964	30.000	-2.782	30.129
15	L15 (5-4)	1.2946	5.591	-12.329	13.538
16	L16 (2-5)	1.3452	13.316	-10.433	16.917
17	L17(5-6)	1.456	15.835	-4.624	16.496
18	L18(4-9)	1.3755)	7.429	-12.666	14.684
19	L19 (4-7)	1.3699	-35.077	0.840	35.087
20	L20 (8-7)	1.1686	-9.075	7.393	11.705

Table 8 show the system overload with 10%, as can be seen, still the Line 6 is showing high power surge with both 231.029 MW and 231.029 MVA surge , these results confirming to the result in the voltage flow analysis where bus 6 show the violation of the power criteria.

Table 8. Under 10% overloaded

S.no	Line out stage	Maximum loading	**P (MW)**	**Q (MVar)**	**S (MVA)**
1	L1(6-5)	1.433	231.029	1.244	231.054
2	L2(6-12)	1.24	98.902	16.049	100.196
3	L3(12-13)	1.4286	33.950	0.132	33.950
4	L4(6-13)	1.0457	67.993	4.271	68.127
5	L5 (6-11)	1.2666	70.533	4.479	70.675

6	L6(11-10)	1.3191	31.029	1.244	41.054
7	L7(9-10)	1.4876	6.193	-1.814	6.453
8	L8(9-14)	1.6338	58.391	2.902	58.463
9	L9(14-13)	1.3615	23.560	0.490	23.565
10	L9(7-9)	1.0237	73.728	16.372	75.524
11	L11(1-2)	1.3375	-7.204	-2.949	7.785
12	L12(3-2)	1.3536	51.231	14.724	53.304
13	L13 (3-4)	1.4387	29.702	-8.402	30.867
14	L14(1-5)	1.3964	30.000	-2.782	30.129
15	L15 (5-4)	1.2946	5.591	-12.329	13.538
16	L16 (2-5)	1.3452	13.316	-10.433	16.917
17	L17(5-6)	1.456	15.835	-4.624	16.496
18	L18(4-9)	1.3755)	7.429	-12.666	14.684
19	L19 (4-7)	1.3699	-35.077	0.840	35.087
20	L20 (8-7)	1.1686	-9.075	7.393	11.705

As explained the voltage range for all the bus in the 14-buses test system is from 0.95 to 1.05. Thus if the voltage at the bus is not in the range. Here, it can be seen that two line configuration were violating system. These are 227.603 MA and 238.602 MVA with 248.902MV and 210.196 MVA. This similar to the voltage analysis .

Conclusion

The 14-bus power system analysis was successfully conducted with following conclusion. The 14 buss Power system was analyzed under normal, 5%, 10%, 15%, 20% overload. Based on power (N-1) contingency analysis and power flow analysis, the system security level was assessed. The system show serious uncertainties with both power flow analysis and contingencies show similar system behaviors. However, there was stable at the normal and 5% overload but the severity of the system increase with the overload is increased. In order to complement the system problem, VPP was introduced and the results of energy production analysis show that the excess electricity is generated 2,034, 920MWh with Revenue of $203,492,014 and 880,275 GHG emission reduction and an early payback period is recorded. Likewise, the system stability improved.

References

[1.] Saadat, Hadi. Power system analysis. WCB/McGraw-Hill, 1999. Niebur, Dagmar, and Alain J. Germond. "Power system static security assessment using the Kohonen neural network classifier." Power Systems, IEEE Transactions on 7.2 (1992): 865-872.

[2.] El-Sharkawi, M. A., and Rajasekhar Atteri. "Static security assessment of power system using Kohonen neural network." Neural Networks to Power Systems, 1993. ANNPS'93., Proceedings of the Second International Forum on Applications of. IEEE, 1993.

[3.] El-Sharkawi, Mohamed, and Steven S. Huang. "Application of query-based learning to power system static security assessment." Neural Networks to Power Systems, 1993. ANNPS'93., Proceedings of the Second International Forum on Applications of. IEEE, 1993.

[4.] Nitve, Bhakti, and Rajani Naik. "Steady state analysis of IEEE-6 Bus System Using PSAT power toolbox." Asija, Divya, et al. "Power flow study and contingency status of WSCC 9 Bus test system using MATLAB." Recent Developments in Control, Automation and Power Engineering (RDCAPE), 2015 International Conference on. IEEE, 2015.

[5.] Mishra, Veenavati Jagadishprasad, and Manisha D. Khardenvis. "Contingency analysis of power system." Electrical, Electronics and Computer Science (SCEECS), 2012 IEEE Students' Conference on. IEEE, 2012.

[6.] Assis, T. M. L., A. A. Nohara, and T. M. Valentini. "Power system dynamic security assessment through a neuro-fuzzy scheme." Intelligent System Applications to Power Systems, 2009. ISAP'09. 15th International Conference on. IEEE, 2009.

[7.] Lerch, E., and O. Ruhle. "Dynamic Security Assessment to protect systems after severe fault situations." Power System Technology, 2006. PowerCon 2006. International Conference on. IEEE, 2006.

[8.] Quirós-Tortós, Jairo, et al. "On evaluating the performance of intentional controlled islanding schemes." Power and Energy Society General Meeting (PES), 2013 IEEE. IEEE, 2013.

[9.] Prajapati, Jackson, Vaibhav Patel, and Harshida Patel. "Load flow, short circuit and stability analysis using Matlab." Green Computing Communication and Electrical Engineering (ICGCCEE), 2014 International Conference on. IEEE, 2014.

[10.] Zimmerman, Ray Daniel, Carlos Edmundo Murillo-Sánchez, and Robert John Thomas. "MATPOWER: Steady-state operations, planning, and analysis tools for power systems research and education." Power Systems, IEEE Transactions on 26.1 (2011): 12-19.

[11.] Totonchi, Ibrahem, et al. "Sensitivity analysis for the IEEE 30 bus system using load-flow studies." Electric Power and Energy Conversion Systems (EPECS), 2013 3rd International Conference on. IEEE, 2013.

[12.] Shetye, Komal S., Thomas J. Overbye, and James F. Gronquist. "Validation of power system transient stability results." Power and Energy Conference at Illinois (PECI), 2012 IEEE. IEEE, 2

[13.] C. S. Indulkar, K. Ramalingam. "Load Flow Analysis with Voltage Sensitive Loads", 2008 IEEE.