Maximum Loadability Limit of Power System using PSO Method

Had Maksimum Beban pada Sistem Kuasa Menggunakan Kaedah PSO

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ABSTRACT

Day-by-day the power system is becoming heavily loaded due to the power demand. Moreover, power system may collapse if exceed its loadability limit. The consequence from overload is entire system might blackout. Blackout need to be avoided especially in industrial as they can suffer losses. Therefore, the objective of this project is to find the maximum load limit each bus can support before collapsed. The highest load value is the maximum limit of load that bus can support. Fast Voltage Stability Index (FVSI) is line stability index which is to determine the critical line of the bus but for this project the goal of FVSI is to identify the weak buses in the system. The bus that its FVSI value closes to 1 is considered as weak bus. In addition, the maximum loadability limit of bus system can be calculated using conventional methods likes Newton-Raphson method but it is quite difficult and time-consuming. Therefore, the Evolutionary Computation technique namely Particles Swarm Optimization (PSO) is used to optimize FVSI value to determine the maximum loadability limit for each bus. PSO and FVSI are tested in IEEE 6-bus system and IEEE 30-bus system. Both FVSI and PSO are simulated using MATLAB software.

Keywords: Particles Swarm Optimization, Fast Voltage Stability Index, Maximum Loadability

ABSTRAK

Sistem kuasa menjadi semakin terbeban setiap hari kerana permintaan tenaga yang tinggi. Seterusnya, keruntuhan sistem kuasa mungkin berlaku jika sistem melebihi had beban. Akibat apabila lebih muatan beban ialah seluruh sistem berkemungkinan berlakunya litar pintas. Perkara ini perlu dielakkan terutamanya dalam perindustrian kerana mereka akan mengalami kerugian. Oleh itu, objektif projek ini ialah untuk mencari had maksimum beban pada setiap bas yang dapat ditampung oleh bas tersebut sebelum berlaku keruntuhan sistem. Nilai beban yang paling tinggi adalah merupakan had maksimum beban yang dapat ditampung oleh bas. Indeks Kestabilan Voltan Pantas(FVSI) ialah indeks kestabilan talian di mana untuk menentukan talian bas yang kritikal. Namun, tujuan FVSI dalam projek ini ialah untuk mengenal pasti bas yang lemah dalam sistem. Bas yang mempunyai nilai FVSI yang menghampiri 1 dianggap sebagai bas yang lemah. Tambahan pula, pengiraan had maksimum beban bagi sistem bas boleh dikira dengan menggunakan kaedah lazim seperti kaedah Newton-Raphson tetapi ianya sedikit susah dan mengambil masa. Maka, teknik pengiraan berevolusi iaitu Pengoptimuman Kumpulan Zarah (PSO) digunakan untuk mengoptimumkan nilai FVSI bagi menentukan had maksimum beban untuk setiap bas. Kaedah PSO dan FVSI diuji pada sistem IEEE 6-bas dan sistem IEEE 30-bas. Kedua-duanya iaitu PSO dan FVSI disimulasikan dengan menggunakan perisian MATLAB.

Kata kunci: Pengoptimuman Kumpulan Zarah, Indeks Kestabilan Voltan Pantas, Beban Maksimum

INTRODUCTION

The high demand in electricity is the key concern in the planning and operating power system. Continuous requests from customers can cause the power system to operate until maximum level (Mehdi et al. 2011). The high demand of electricity all the time causes it to become stressed. As the power system is heavily loaded, it become unstable and leading system to operate close to their limit.

The voltage collapse because of the disruption in power supplies is ever happened in few countries; 14th August 2003 in New York, 29th August 2003 in London, 23rd September 2003 in Denmark and Sweden, 30th September 2003 in Italy, 18th August 2005 in Java-Bali, and 10th-11th November in Brazil and Paraguay (Acharjee 2011). So, the analysis of power system voltage stability is very important in an electrical field to avoid electricity breakdown from frequently happens (Goh et al. 2015).

Many of line stability indices can be used to search the maximum loadability limits. One of them is FVSI. The concept of FVSI is based on power flow through a single line. The most critical line of the bus is the line that gives index value closest to 1 and this may lead in determining the weakest bus on the system(Abedelatti et al. 2015). The maximum load that allowed on a load bus is the weakest bus (Reis 2006). Evolutionary Computation Technique is technique for power system application. One of the famous techniques to be used is PSO technique. It is popular amongst the authors. Acharjee makes comparison between real coded security constraint Genetic Algorithm and PSO for Maximum Loadability Limit Problem (Acharjee 2011). El-Dib *et al* used Hybrid PSO to determine maximum loadability limit and make comparison with Continuation Power Flow (Uri 2014). PSO is quite famous technique because of its simplicity, easy implementation, and reliable convergence. The general PSO parameters only using simple algorithm (Acharjee et al. 2009). It can be used to solve non-linear optimization problems. It has been used in various applications, reactive power and voltage control, optimal power flow, power system reliability and security, and others (Acharjee et al. 2009).

Indices based upon conventional methods likes Newton-Rahpson can be used to calculate the weak buses. But this method require repeated power flow solution, therefore, it is time-consuming (Ratra et al. 2018). In this project, the proposed methods are FVSI and PSO.

METHODOLGY

This project implement on IEEE bus system. The IEEE bus system is used as tested bus because of its power flow data is valid. The proposed IEEE bus system is 6-bus system and 30-bus system. Figure 1 and Figure 2 is IEEE 6-bus and IEEE 30-bus respectively. The 6-bus system has 7 lines while 30-bus system has 41 lines.

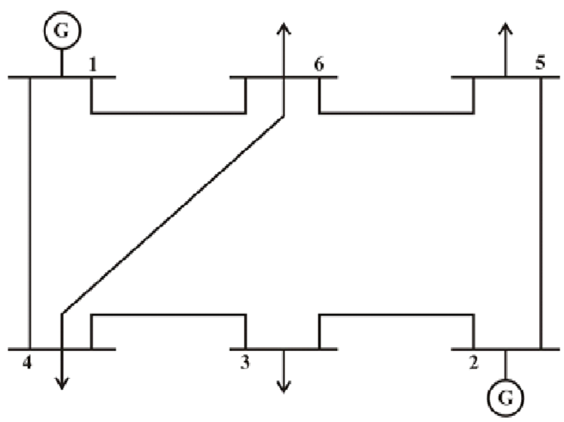

FIGURE 1. IEEE 6-bus system

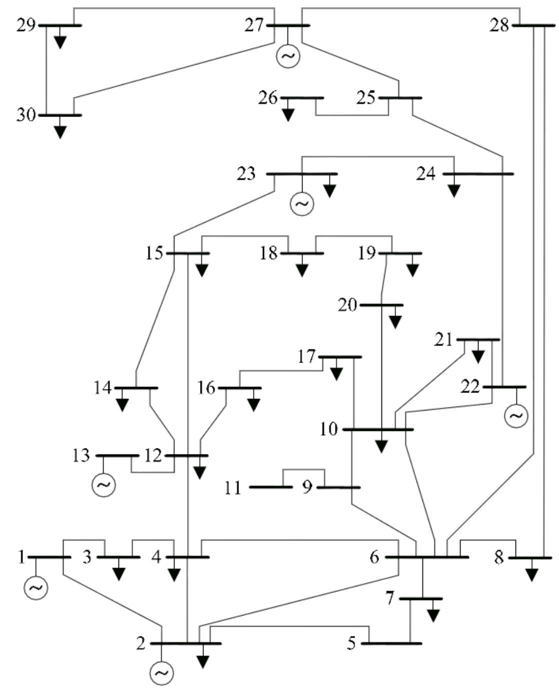

FIGURE 2. IEEE 30-bus system

Fast Voltage Stability Index (FVSI)

FVSI is proposed by Ismail Musirin and Titik Khawa Abdul Rahman in 2002. A bus or a line can refer this index. Therefore, it is capable to identify weak bus in the system. In this project, FVSI is used to search the maximum load value in bus with 100 iterations for each bus. The each load of bus is calculated using following formula.

$$FVSI = \frac{4z^2 Q_j}{V_i^2 x} \quad (1)$$

where,

Z = line impedance
X = line reactance
Q_j = reactive power flow at receiving end
V_i = sending end voltage

The level value that indicates the particular line is close to its stability point is 1. Therefore, if FVSI value almost reached value 1, it shows the maximum load value of that bus.

Particles Swarm Optimization (PSO)

Basically, there are a few optimization methods such as Grey Wolf Optimizer, Evolutionary Programming, and so on. PSO is evolution calculation technique developed by Dr. Russ Eberhart and Dr, James Kennedy (Kamari et al.

2013). This method is Evolutionary Computation or meta-heuristic technique. PSO can be applied in reactive power and voltage control, reliability of power system, optimal flow power, and so on.

PSO is a technique where its solution algorithm is based on population. This technique has been used to analyze the behavior of species biology likes a flock of bird and a school of fish in their actions of looking for food. But now PSO can use in practical problem analysis that related in maximum load limit.

The following scenario tells about PSO holistically in term of its behavior. A flock of bird was finding food which is located at minimum distance from their nest. The birds are then divided into small group and they are start looking food in small group. If there is a group that found the best food place, others group will move to that food place with their intelligence. Therefore, the birds can achieve optimal location of food after doing it repetitively (Kumar et al. 2015).

In this project, PSO is applied in optimize the load value in FVSI to determine the maximum load limit that each bus can support.

$$PSO = \omega v + c_1 r(x_{best} - x) + c_2 r\left(x_{global} - x\right) \tag{2}$$

where,

c_1, c_2 = acceleration coefficients
ω = inertia weight
r = random function

The FVSI value from 100 iterations is ranked in descending order. The highest value is the maximum FVSI value in bus. The maximum FVSI value is considered as local best value, x_{best} for that particular bus. This applied for each bus. x_{best} that obtained from each bus is then ranked again from highest to lowest. The highest value of x_{best} is saved as global best value, x_{global}. Then, PSO optimized the value and the highest load in FVSI value is maximum load limit that bus can support.

Figure 3 shows the optimization of particles using PSO method. Meanwhile, Figure 4 is the flowchart on how PSO method works on.

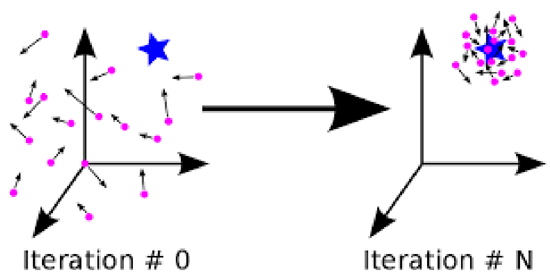

FIGURE 3. Optimization of particles using PSO

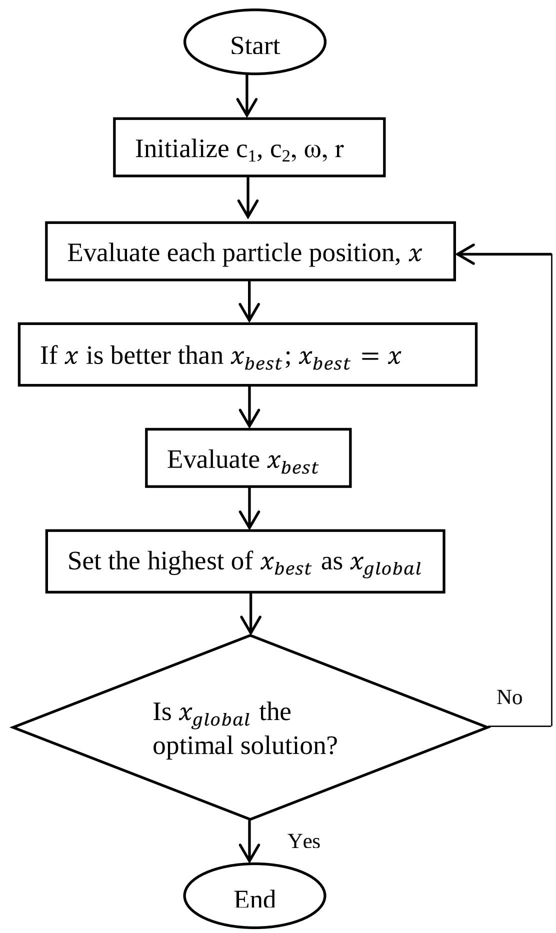

FIGURE 4. PSO flowchart

RESULTS AND DISCUSSION

Bus 1 is not included because it is a reference bus. Therefore, its load is zero. The load limit and FVSI value for bus 2 until bus 6 for 6-bus system are tabulated in Table 1.

TABLE 1. Load limit and FVSI value of 6-bus system

Bus Number	Load (MW)	FVSI Value
2	76.7791	0.7760
3	136.5282	0.8969
4	108.6728	0.7968

5	50.9830	0.3671
6	136.8691	0.8491

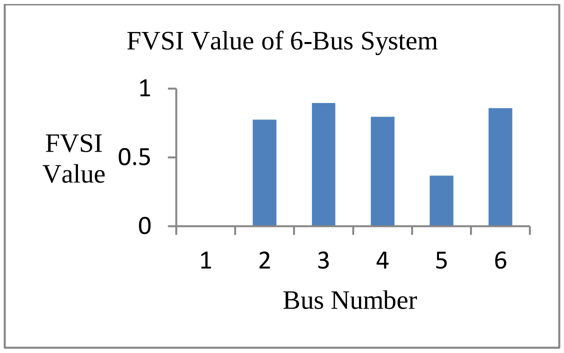

FIGURE 5. Bar graph of FVSI value of 6-bus system

Based on Figure 5, the highest FVSI value for 6-bus system is 0.8969 which is at bus 3. The maximum load limit that system can support is at bus 6 with 136.8691 MW. If load is over that value, bus 6 will collapse and it may affect the entire system. The lowest FVSI value in the system is 0.3671 at bus 5. The minimum load is also at bus 5 with load value of 50.9830 MW.

Table 2 is the load limit and FVSI value of bus 2 until bus 30 for 30-bus system.

TABLE 2. Load limit and FVSI value of 30-bus system

Bus Number	Load (MW)	FVSI Value
2	710.4557	0.3354
3	533.7875	0.8739
4	592.7608	0.9821
5	593.6774	0.4701
6	650.2154	0.8923
7	518.2250	0.8182
8	598.3411	0.8147
9	199.2537	0.5257
10	249.5796	0.8163
11	278.1556	0.5606
12	198.1350	0.3795
13	263.5991	0.8658
14	134.5042	0.5358
15	212.6415	0.9858
16	188.1913	0.7965
17	198.9395	0.7159
18	129.4750	0.6014
19	134.8540	0.6480
20	141.1894	0.8065
21	199.8094	0.6915
22	199.9142	0.8324
23	131.3240	0.6094
24	152.5138	0.7051
25	96.7191	0.4805
26	40.8337	0.2694
27	114.7917	0.3864
28	486.8339	0.8918
29	48.8702	0.2888
30	49.3991	0.2748

Refer to Figure 6, the highest FVSI value is 0.9858 which is at bus 15. Meanwhile, based on Table 2, the maximum load limit the bus system can support is at bus 2 with load value of 710.4557 MW.

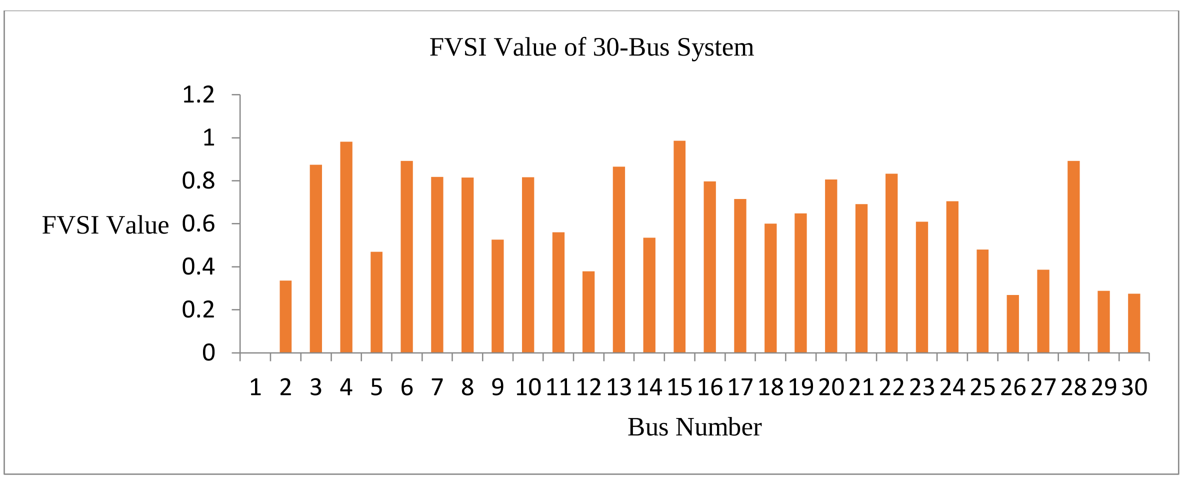

FIGURE 6. Bar graph of FVSI value of 30-bus system

CONCLUSION

Each bus has different load limits although they are in the same system. This same goes with FVSI value. The highest FVSI value does not necessarily have the maximum load limit. FVSI value that closes to 1 is considered as weak buses. The weak bus in 6-bus and 30-bus is at bus 3 and bus 15 with FVSI value of 0.8969 and 0.9858 respectively. From Table 1 and Table 2, it can be concluded that the maximum limit for 6-bus and 30-bus is 136.8691 MW and 710.4557 MW respectively.

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