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Enhancement of Voltage Profiles of Buses of the Interconnected Power System in MATLAB/Simulink Platform

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Abstract

The enhancement of the voltage profile of power system bus bars is one of the key requirements for the stable operation of the system. Because whenever the voltage instability occurs in the network, it can cause serious voltage decline. The value of the voltage profile may cross the acceptable limit and result in the interruption of power flow. There are many ways available for the enhancement of voltage profile. Reactive power has a direct influence on the improvement of voltage profile so reactive power injection at a particular bus bar can enhance the voltage profile of that bus bar. In this paper, a capacitor is used for the reactive power compensation on the bus bar having a weak voltage profile. The simulation is carried out in MATLAB/Simulink. For simulation, a standard IEEE 5 bus model has been considered. The simulation results have appeared as it is expected.

Keywords: Voltage profile, Reactive power, Power Flow Analysis.

I. Introduction

In recent decades, because of the increasing demand for electrical energy, renewable energy sources are encouraged to generate more electricity independently or with the help of the interconnected network to satisfy the energy demand. In an interconnected network, these renewable energy sources have to integrate with the grid with conventional energy sources. But the power quality and voltage stability of that interconnected network can be hampered while generating a large amount of electricity with the help of renewable energy sources. Besides, the electricity market has been deregulated because of more diverse market players available in the generation and load sides. So in the deregulated electricity market, continuous use of a large transmission system can hit the stability limit of voltage profile (B. Singh *et al.*, 2018)**.** Because poor scheduling of generation companies for participating in the competitive bidding can initiate the voltage instability of the network (P. Thannimalai *et al.*, 2015).The complexity of the network increase with the size of the transmission network. For the reliable operation of the grid, power quality and voltage stability are giving more challenges to maintain at a certain level. Otherwise, the system may lose its stability and the result would be the interruption of power transfer. It is broadly realized that due to the reformation of the power network and restructuring of utility economics many companies are compelled to operate near to their stability limit and unconsciously forced towards the voltage collapse (F. Dong *et al.*, 2004). To be more specific, when a power network operates close to the voltage stability limit, the voltages at some of the bus bars decrease rapidly and the operators fail to retain the voltage at a certain level. In some cases, they may exaggerate the situation and the result is the voltage collapse of the network. This event is providing continuous challenges to the network operator for providing proper security and reliability of the system (G. A. Mahmoud, 2012).

There is a direct relation between voltage profile and reactive in the power network. So, any variation in reactive power consumption at any bus changes the value of the voltage profile of that bus. As the reactive power demand increases the voltage profile goes down below its rated value. For the case of the generator bus, the exciter of the generator can help to improve the voltage profile

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to a certain level. But for the load bus or PQ bus, this provision is not available. So reactive power injection can improve the voltage profile of the PQ bus significantly. Some basic idea of voltage profile control is given in (D. P. Kothari *et al.*, 2013) including voltage control by the generator, voltage control by SVC and voltage control by tap changing transformer and other power electronic controller. An analysis is given on voltage profile enhancement using SVC and STATCOM devices (F. Ahmad, 2019). In (S. Kumar J *et al.*, 2011, M. J. Katira *et al.*, 2009) some special techniques have been considered to improve the voltage stability using SVC and UPFC. Voltage instability issue using load flow in MI Power software is explained in (V. Parmar *et al.*, 2018).

In this paper, a standard IEEE 5 bus power network has been considered for the analysis. Based on the specification given in (T. Gönen, 2013) a MATLAB/Simulink model has been developed. To analyze the response of the system a power flow analysis is conducted. From the power flow data, bus voltages are compared with the rated voltage. From the analysis, a capacitor bank is installed on the bus bars with a low voltage profile to improve the voltage profile of that bus.

II. Power Flow Analysis

Static Power flow analysis is one of the key parts of this paper because it can give a clear idea about the voltages of different buses. With the help of Power flow analysis, the magnitudes of the voltages with angles, real power, and reactive power of different buses of the network can be found in a tabular form.

III. Specifications of the Network under Study

The IEEE 5 bus system is given in figure 1. There are two generators available in this system. One generator is on bus 1 which is considered as the slack bus with a voltage profile of $1.02\angle 0°$ pu. Another generator is on bus 4 which is considered as a PV bus with the voltage magnitude 1.05 pu. Bus 2,3 and 5 are the PQ buses. A tap changing transformer is connected between bus 2 and 3 and a capacitive load is connected on bus 4. The base voltage of the system is considered as 1 kV and the base power of the entire system as 1 MVA. The initial value of the 5 bus system is given in Table I. The line data is given in Table II.

Table I: Initial values of IEE 5 bus system

Bus No	Voltage Magnitude (pu)	Voltage Angle (degree)	Real Power P (pu)	Reactive Power Q (pu)	Bus Type
1	1.02	0			Slack bus
2	1	0	0.7	0.2	PQ bus
3	1	0	0.4	0.1	PQ bus
4	1.05	0	0.0	-0.2	PV bus
5	1	0	0.6	0.3	PQ bus

Table II: Line data of the system

Bus from and to	Impedance (pu)	Type
1 to 2	0.2+j0.4	Transmission line
1 to 5	0.1+j0.2	Transmission line
2 to 3	j0.2 and tap ratio, a =0.9091	Tap changing transformer
2 to 4	0.1+j0.2	Transmission line
4 to 5	0.2+j0.4	Transmission line

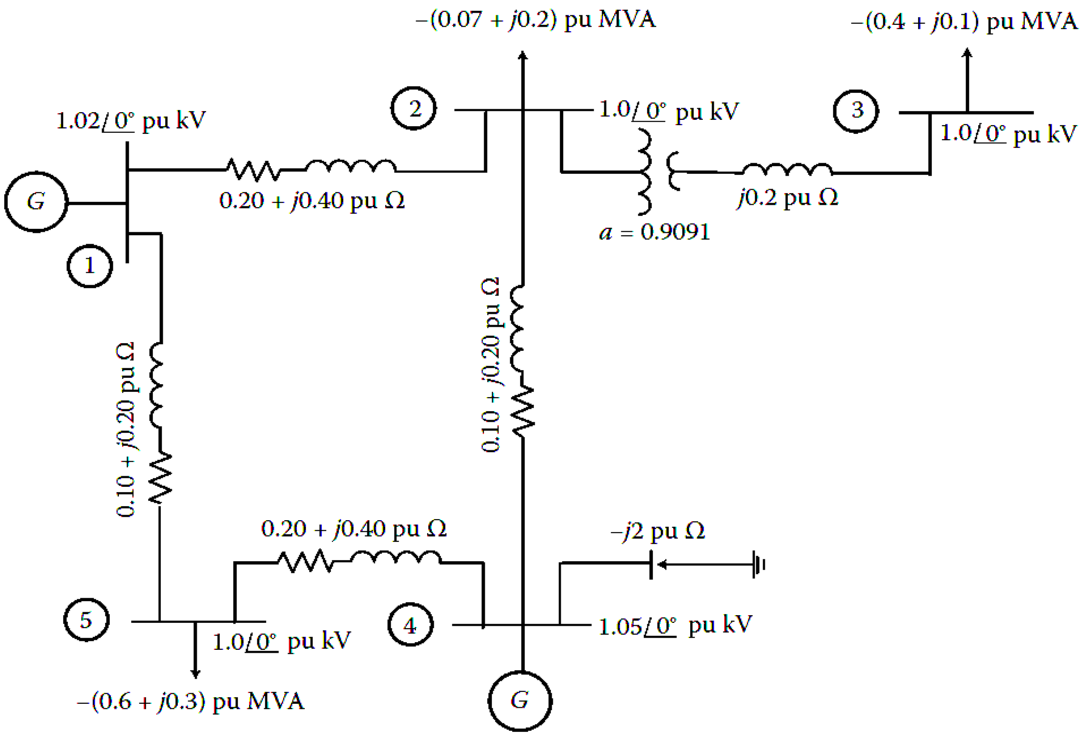

Figure 1: Single line diagram of IEEE 5Bus System

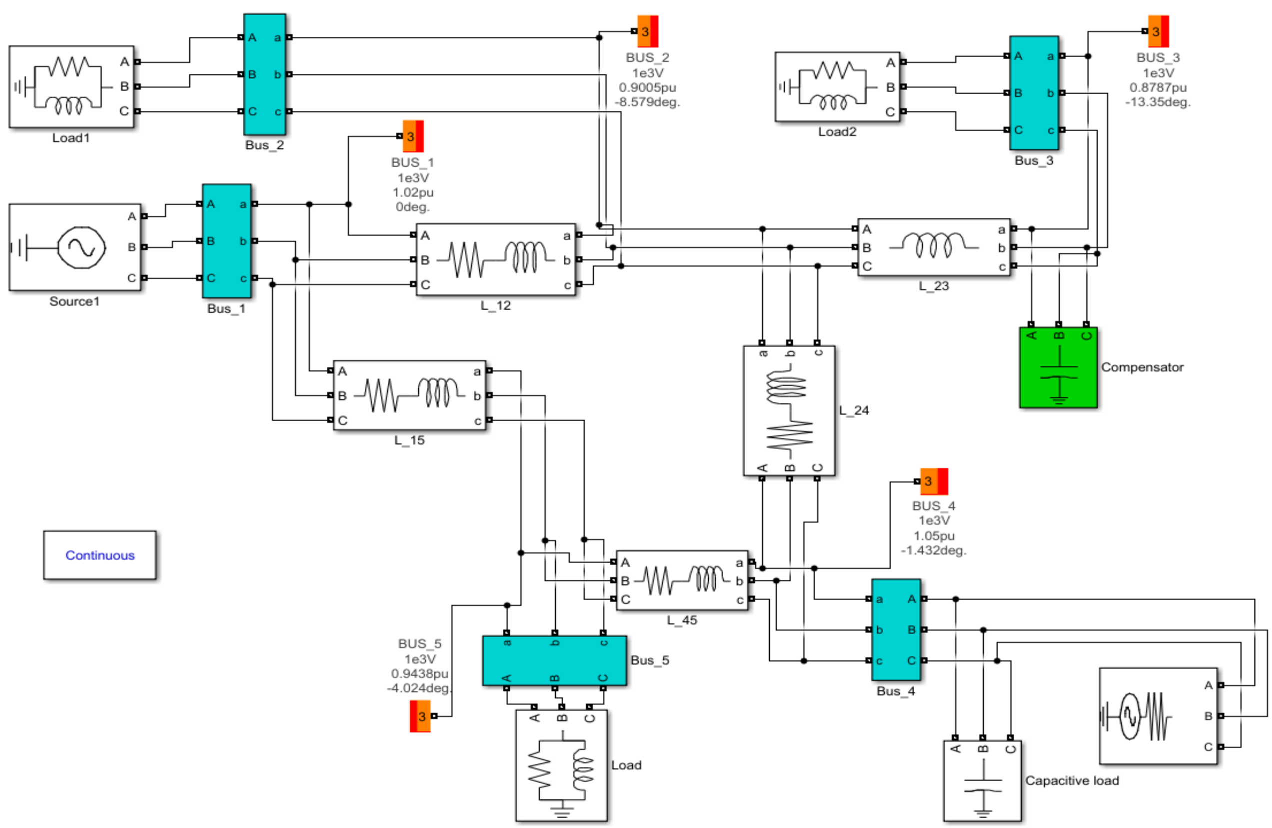

Figure 2: Simulink model of the IEEE 5 Bus System with an additional capacitor on bus 3

IV. Simulation Model of the System

The simulation model is developed in MATLAB/Simulink based on the information given in Table I and Table II of the previous section. The developed Simulink model of the IEEE 5 Bus System with an additional capacitor on bus 3 is given in Fig. 2. Generator at bus 1 is represented by an ideal three-phase voltage source. Generator at bus 4 is represented by a three-phase voltage source with a very small amount of series resistance because in Simulink a capacitor cannot be connected with an ideal voltage source. However, this resistance is very small so it will have very little impact on the result. The value of the capacitive load on bus 4 is 2 MVAR. The value of the capacitor used for reactive power compensation on bus 3 is 0.38 MVAR.

Table III: Load flow analysis of IEEE 5Bus system under an initial condition with no capacitor on bus 3

Sl#	Block Type	Bus Type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	V-LF (pu)	Vangle-LF (deg)	P-LF (MW)	Q-LF (MW)
1	Vsrc	swing	BUS-1	1.00	1.02	0.00	0.01	0.00	1.0200	0.00	0.84	0.31
2	RLC load	PQ	BUS-5	1.00	1.00	0.00	0.60	0.30	0.9438	-4.02	0.60	0.30
3	RLC load	PQ	BUS-2	1.00	1.00	0.00	0.70	0.20	0.9005	-8.58	0.70	0.20
4	RLC load	Z	BUS-4	1.00	1.05	0.00	0.00	-2.00	1.0500	-1.43	0.00	-2.21
5	Vsrc	PV	BUS-4	1.00	1.05	0.00	1.00	0.00	1.0500	-1.43	1.00	-1.60
6	RLC load	PQ	BUS-3	1.00	1.00	0.00	0.40	0.10	0.8787	-13.35	0.40	0.10

Table IV: Load flow analysis of IEEE 5Bus system adding a capacitor at the bus no 3

Sl#	Block Type	Bus Type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	V-LF (pu)	Vangle-LF (deg)	P-LF (MW)	Q-LF (MW)
1	Vsrc	swing	BUS-1	1.00	1.02	0.00	0.01	0.00	1.0200	0.00	0.82	0.18
2	RLC load	PQ	BUS-5	1.00	1.00	0.00	0.60	0.30	0.9438	-3.95	0.60	0.30
3	RLC load	PQ	BUS-2	1.00	1.00	0.00	0.70	0.20	0.9005	-9.44	0.70	0.20
4	RLC load	Z	BUS-4	1.00	1.05	0.00	0.00	-2.00	1.0500	-1.19	0.00	-2.21
5	Vsrc	PV	BUS-4	1.00	1.05	0.00	1.00	0.00	1.0500	-1.19	1.00	-1.88
6	RLC load	PQ	BUS-3	1.00	1.00	0.00	0.40	0.10	1.0015	-13.39	0.40	0.10
7	RLC load	Z	BUS-3	1.00	1.00	0.00	0.00	-0.38	1.0015	-13.39	0.00	-0.38

V. Result Analysis

First, a power flow analysis is performed with the specified data given in section III. The result of the power flow analysis is given in Table III. Figure 3 is plotted based on the voltage data of different buses of Table III.

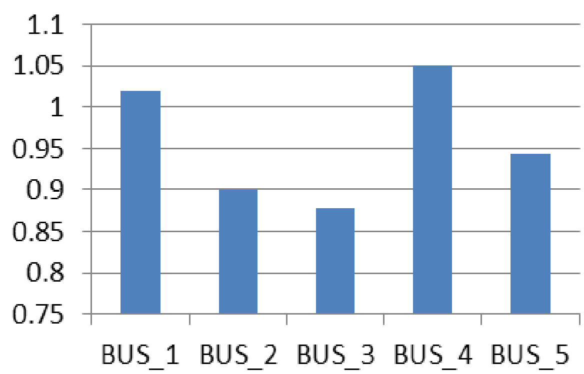

Figure 3: Bus voltage of the system under the initial condition

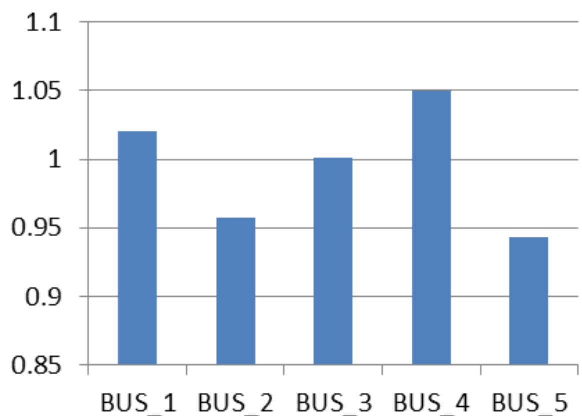

Figure 4: Bus voltage of the system with a capacitor at bus 3

From this figure, it is found that the voltage at bus 3 is 0.8787 pu, which is very low. Bus 3 is a load bus so there is no option to change the excitation of the generator to improve the voltage profile of that bus. So to improve the voltage profile to 1 pu of that bus a capacitor is connected on bus 3. A capacitor reactive power injection capacity of 0.38 Mvar has been installed on bus 3. With all other parameters fixed a power flow has been performed again and found the desire voltage level on bus 3 which can be seen from the power flow result of Table IV.

VI. Conclusions

This paper analyzes the voltage profile enhancement technique with the help of the power flow of a standard IEEE 5 bus system. The power flow result using Simulink can indicate the result as it is expected from the system. After analyzing the result the weaker bus is selected which is bus 3. After adding an appropriate amount of capacitor, the voltage profile of that bus is improved. In the future, more advanced techniques of voltage profile improvement can be analyzed. A more complex network with more generators and loads can be considered for future analysis.

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