International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064

Enhancement of Transient Stability in a 9 Bus System using Matrix Converter Based UPFC

Selvamani Prabaharan .M[1], Lakshmanan .P[2]

[1]P.G Student (PSE), Dept. of EEE, V.S.B. Engineering College, Karur, Tamil Nadu, India

[2]Associate Professor, Dept. of EEE, V.S.B. Engineering College, Karur, Tamil Nadu, India

Abstract: ***Due to the increase in population, the power demand also increases and as a result we are in a situation to commission new power plants and transmission lines. The right of way and higher cost incurred in installing new transmission lines forced us to use the transmission lines up to its higher loadable limit. The loading limit of transmission lines up to steady state stability limit is not allowed by transient stability limits. In order to utilize the lines up to its maximum, the transient stability need to be improved. In this paper the transient stability of IEEE nine bus systems is studied under severe disturbance in MATLAB-Simulink environment. ANN based controller is employed to control the matrix converter based UPFC and the results obtained with and without UPFC is compared.***

Keywords: Transient stability, Matrix converter, ANN, UPFC, MATLAB-Simulink.

1. Introduction

Transient stability is defined as the system's ability to come back to normal operation after a large disturbance without moving away from synchronism. If a system is operated above transient stability limit but less than steady state stability limit, immediately after a large disturbance, the system may loss synchronism and it lead to loss of generation which causes the other generators to overload and as a consequence it may even lead to black out. The emergence of power electronic devices in the past two decades and introduction of FACTS devices is a great boon to power engineers. The application of FACTS devices will improve transient stability limit and allow the system to operate near the steady state stability limit. Among all the FACTS devices the most important device is UPFC. The major disadvantage of using conventional UPFC is the usage of large DC link capacitor which increases its cost, foot print and lead to its reduction in performance due to the ageing of DC link capacitor.

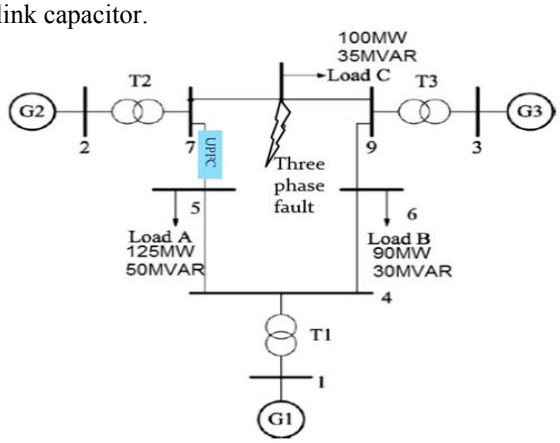

Figure 1: Single line diagram showing fault and UPFC location

The usage of matrix converter based UPFC will overcome all the above disadvantages. In this paper transient stability of IEEE nine bus system is improved using ANN controlled Matrix converter based UPFC. The result obtained in case of without and with UPFC is analyzed.

2. Conventional UPFC

It is a combination of SSSC and STATCOM. It consists of series and shunt connected voltage source inverters connected via a DC link. The shunt connected converter is used for maintaining the DC link voltage whereas the series connected inverter is used for injecting the real and reactive power into the line. The cost, size, performance reduction due to ageing is the major disadvantages of the DC link capacitor employed.

3. Matrix Converter Based UPFC

It contains nine bidirectional switches which replace the shunt, series converters and the DC link capacitor in the conventional UPFC. There are 512 switching combinations available and out of that only 27 switching combinations are permitted. The permitted combinations is based on the following rules ,the input phases will not be short circuited and the output will not be open circuited at any instant of operation. Only three switches are conducting at a time and the switching loses are also minimized in comparison with conventional UPFC. Each output waveform is obtained by sequential sampling of input waveform. Due to the absence of energy storage elements in matrix converter, the output voltage is obtained from input voltages. The required output waveform is got by sampling the input waveform sequentially

Since no energy storage components are present between the input and output sides of the matrix converter, the output voltages have to be generated directly from the input voltages. Each output voltage waveform is synthesized by sequential piecewise sampling of the input voltage waveforms. The input voltage equations for Matrix converter is, as follows:

$$V_a = V_m \cos\theta_{av} = V_m \cos(\omega t) \quad (1)$$

$$V_b = V_m \cos\theta_{bv} = V_m \cos(\omega t - (\frac{2\pi}{3})) \quad (2)$$

$$V_c = V_m \cos\theta_{cv} = V_m \cos(\omega t + (\frac{2\pi}{3})) \quad (3)$$

The line side current in the shunt side is described as,

$$I_a = I_m \cos\theta_{av} = I_m \cos(\omega t - \psi_{In}) \quad (4)$$

$$I_b = I_m \cos\theta_{bv} = I_m \cos(\omega t - (\frac{2\pi}{3}) - \psi_{In}) \quad (5)$$

$$I_c = I_m \cos\theta_{cv} = I_m \cos(\omega t + (\frac{2\pi}{3}) - \psi_{In}) \quad (6)$$

The sampling rate has to be set much higher than both input and output frequencies, and the duration of each sample is controlled in such a way that the average value of the output waveform within each sample period tracks the desired output waveform. As consequence of the input ± output direct connection, at any instant, the output voltages have to fit within the enveloping curve of the input voltage system. The output voltage injected into the transmission line:

$$V_u = V_0 \cos\theta_{au} = V_0 \cos(\omega t + \varphi_0 + \psi_{out}) \quad (7)$$

$$V_v = V_0 \cos\theta_{av} = V_0 \cos(\theta_{au} - (\frac{2\pi}{3})) \quad (8)$$

$$V_w = V_0 \cos\theta_{cw} = V_0 \cos(\theta_{au} + (\frac{2\pi}{3})) \quad (9)$$

4. System Description

The nine bus system consists of three generator buses and three load buses. The generating voltages of three generators are at different voltage levels but they are stepped up into 230 kV for transmission purpose. The nine bus system is shown in the Fig. 1. Three phase fault is simulated in the bus 8 and the UPFC is connected between the buses 5 and 7. Buses 5,6 and 8 are load buses which are having load of 125MW, 90MW and 100 MW respectively. The machine ratings and other details are attached in appendix. The simulation diagram in MATLAB-Simulink environment is shown in Fig. 2.

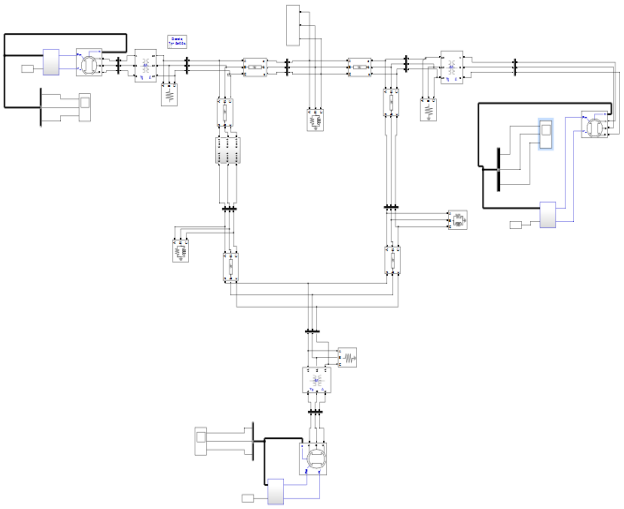

Figure 2: Simulation diagram with Matrix converter based UPFC

5. ANN Training

The input and output data from the PI controller is exported to the workspace. The Neural network training tool is selected and the input and targets are imported from the workspace. The number of neurons is selected as fifteen and the neural network controller is trained until the mean square error is closer to zero and the regression value is closer to one. The mean square error is defined as the difference between the averaged square of input and target whereas regression is defined as the correlation between output and target. The value of regression one means a closer relationship between input and target and zero means a random relationship. After the completion of training, the simulation diagram for the trained ANN controller is generated and it is used in the simulation.

6. Results and Discussion

Three phase fault is simulated in bus 8 for duration of 0.3 to 0.33 seconds. The real power, reactive power and load angle of generator 1 are 0.3pu, -0.2pu and 5 degree respectively during normal operation whereas during the fault condition without UPFC it is 15.8pu, 15pu and -180 to 180 degree respectively and with matrix converter based UPFC it is -0.6pu, 2pu and 20 degree respectively which is shown in the Figure 3.

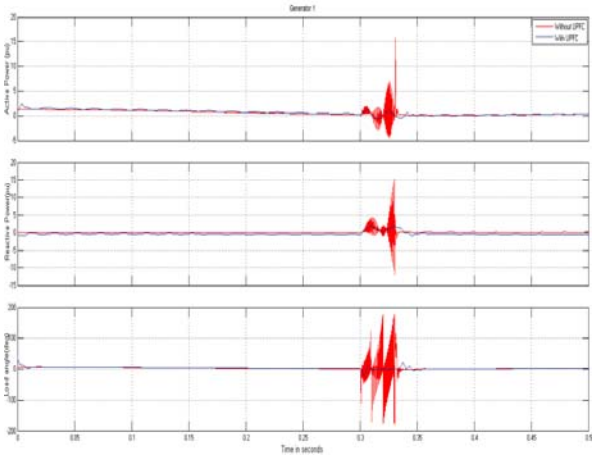

Figure 3: Generator 1 waveforms

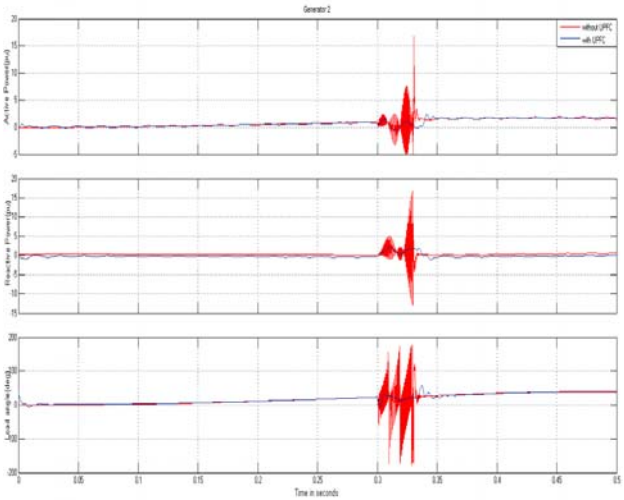

Figure 4: Generator 2 waveforms

The real power, reactive power and load angle of generator 2 are 1.6pu, -0.5pu and 40 degree respectively during normal operation whereas during the fault condition without UPFC it is 17pu, 17pu and -180 to 180 degree respectively and with matrix converter based UPFC it is -0.5pu, 2pu and 60 degree respectively which is shown in the Fig.4.

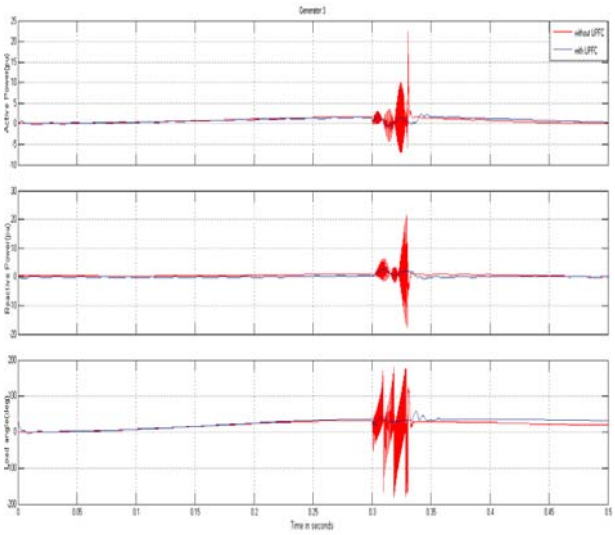

Figure 5: Generator 3 waveforms

The real power, reactive power and load angle of generator 3 are 0.8pu, 0.2pu and 36 degree respectively during normal operation whereas during the fault condition without UPFC it is 22pu, 21.4pu and -180 to 180 degree respectively and with matrix converter based UPFC it is -0.4pu, 2.8pu and 58 degree respectively which is shown in the Fig.5.

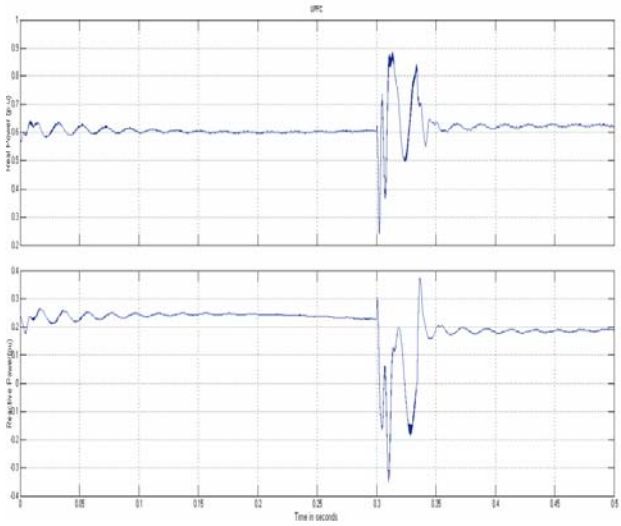

Figure 6: UPFC Real and Reactive power output

During the fault duration the UPFC supplies 0.9 pu of real power and absorbs 0.35 pu of reactive power in the transmission line which is shown in the Fig.6. During fault the load buses 5 and 6 are having voltage of 0.28pu and 0.4 pu respectively without UPFC and with UPFC the bus voltages are maintained as 0.5 pu which is shown in the Fig.7.

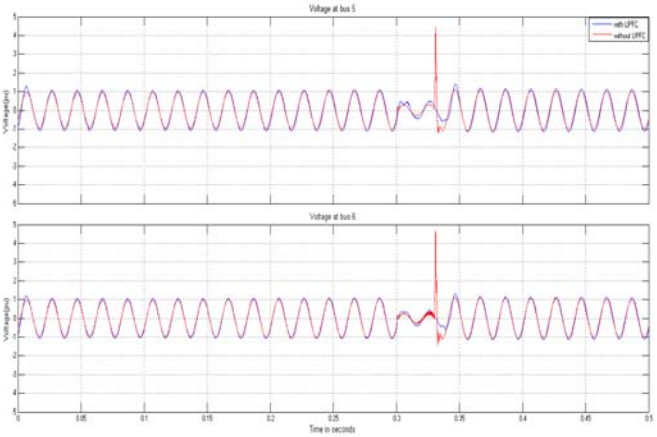

Figure 7: Voltage at buses 5 and 6

Table 1: Comparison of results with and without UPFC

Equipments	*Parameters*	*Normal condition*	*During Fault 0.3 to 0.33 seconds*	
			Without UPFC	*With UPFC*
Gen 1	P(pu)	0.3	15.8	-0.6
	Q(pu)	-0.2	15	2
	DEL(degree)	5	-180 to 180	20
Gen 2	P(pu)	1.6	17	-0.5
	Q(pu)	-0.5	17	2
	DEL(degree)	40	-180 to 180	60
Gen 3	P(pu)	0.8	22	-0.4
	Q(pu)	0.2	21.4	2.8
	DEL(degree)	36	-180 to 180	20
UPFC	P(pu)	0.6	NIL	0.9
	Q(pu)	0.2		-0.35
Bus 5	V(pu)	1.0	0.28	0.5
Bus 6	V(pu)	1.0	0.3	0.5

7. Conclusion

Thus from the above discussion it is clear that the load angle is maintained within 90 degree with the matrix converter based UPFC and the generators are operated in synchronism with improved transient stability and also the load buses voltage other than the faulted bus is also improved.

Appendix

Table 2: Machine Data

Parameters	*M/C 1*	*M/C 2*	*M/C 3*
H(sec)	23.64	6.4	3.01
X_d(pu)	0.146	0.8958	1.3125
X'_d(pu)	0.0608	0.1198	0.1813
X_q(pu)	0.0969	0.8645	1.2578
X'_q(pu)	0.0969	0.1969	0.25
T'_{do}(pu)	8.96	6.0	5.89
T'_{qo}(pu)	0.31	0.535	0.6

Table 3: Exciter Data

Parameters	*Exciter 1*	*Exciter 2*	*Exciter 3*
K_A	20	20	20
T_A(sec)	0.2	0.2	0.2
K_E	1.0	1.0	1.0
T_E(sec)	0.314	0.314	0.314
K_F	0.063	0.063	0.063
T_F(sec)	0.35	0.35	0.35

Table 4: Machine Ratings

S.NO	*Generator*	*Transformer*
1	247.5MVA/16.5 kV	250MVA,16.5Kv/230kV
2	163.2MVA/18 kV	165MVA,18Kv/230kV
3	85MVA/13.8 kV	110MVA,13.8Kv/230kV

References

[1] Gyugyi L, Schauder C D, S L Williams, Rietman T R, Torgerson D R & Edris A, "The unified power flow controller: a new approach to power transmission control ", *IEEE Trans. Power Deliv*., April, Vol. 10, No. 2, 1995.
[2] Gyugyi L & Hingorani N G, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, *IEEE Press*, New York, 1999.
[3] Al-Mamsawi S A, "Comparing and evaluating the voltage regulation of a UPFC and STATCOM", *Electr. Power Energy Syst*., November, Vol. 23, (2003) pp.735–740.
[4] Swaroop Kumar, Nallagalva& Mukesh Kumar Kirar,"Transient stability analysis of IEEE 9-bus Elecric power systems",IJSET, July 2012, Vol. 01, Issue No. 3, pp.161–166.
[5] Mutschler P & Marcks M, "A Direct Control Method for Matrix Converters", *IEEE Trans. On Ind. Elect*., April, Vol. 49, No. 2, (2002) pp.362-369.
[6] Seo J H, Choi C H & Hyun D S, "A new simplified space-vector PWM method for three-level inverters," *IEEE Trans. Power Electron.*, vol. 16, no. 4, July (2001) pp.545–550.
[7] Cataliotti A., Genduso F & Ricco Galluzzo G, "A New Over Modulation Strategy for High-Switching Frequency Space Vector PWM Voltage Source Inverters", *Proceeding of the IEEE ISIE,* July. 2002
[8] Mondal S K, Bose B K, Oleschuk V & Pinto J O P, "Space vector pulse width modulation of three-level inverter extending operation into over modulation region", *IEEE Trans. Power Electron.*, vol. 18, no. 2 March, (2003) pp.604–611.
[9] Mishra S, Dash P K & Panda G, "TS-fuzzy controller for UPFC in a multi machine power system", *Proc. Inst. Elect. Eng., Gen. Transm. Distrib*. Vol. 147, No. 1, (2000) pp.15–22.
[10] Nauck D, Klawon F & Kruse R, Foundations of Neuro-Fuzzy Systems, J. Wiley & Sons, 1997.
[11] Czogala E & Leski J, Neuro-Fuzzy Intelligent Systems, Studies in Fuzziness and Soft Computing, *Springer Verlag*, Germany, 2000.
[12] Chuen-Tsai Sun, Eiji Mizutani, Jyh-Shing Roger Jang, Neuro-Fuzzy and Soft Computing, *Prentice Hall* 1997.
[13] Rassoul Noorossana, Moslem Toosheghanian & Fazlollah Masoumi Gazaneh, Using Genetic Algorithm and Response Surface Methodology for Statistically Constrained Optimization of VSI X-bar Control Charts Under Multiple Assignable Causes and Non Normality, *The International Journal of Advanced Manufacturing Technology,* August 67(2013) pp.2325-2342.