Current Trends in Technology and Science
www.ctts.in, ISSN: 2279-0535, May 2022, Volume: 11, Issue: 3

Improvement of Voltage Stability of Distributed Generation by using Smart Grid Technology

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Abstract: A distributed generation (DG) matches a traditional power generation station. It utilises renewable energy sources (like wind, solar, and hydropower generation). A current study is an approach to handling the reactive power imbalances in the power system for the DG integration. The method deals with finding the optimal location for connecting a compensating device and finding the simulation results with DG interfacing under the normal operating condition of the power system. The results were tested per the IEEE-14 bus standards and set network parameters.

Keywords: *Power System, PSAT, reactive power, voltage stability.*

1. INTRODUCTION

The radial behaviour of the traditional power systems in India allows the power flow from the source station with the capacity of generating several thousand Mega Watts (MW) to the customer ends (like household applications, industry, private and govt. firms). A great deal of power wastage is faced during transmission and the environmental impacts due to the far-off location of the power station. The power demand is increasing continuously, and it is impossible to afford such losses. A good deal of work to minimise these losses has already been done in the past by various researchers and academicians. In the present investigation, new technology was developed for installing small generation units termed Distributed Generation. The DG unit possessed a size varying from KW (Kilo Watt) to MW (Mega Watt), which helps deploy renewable energy sources. The main advantage of using DG is to be stationed at adjacent places to customers, thereby receiving the benefits of reducing transmission losses. The other advantage of the DG unit is that users have a low budget and may easily be installed on the top of the roof to generate their income by connecting to the grid (i.e. solar panel generation unit). In load flow, Reactive power is the power taken by the circuit's reactance. This power is not consumed but flows forth and back between source and load. Its unit is Volt-Amp- reactive (VAr). Reactive power is the one which is writhed mainly by the changes in load demands. In this paper, we are observing to improve the voltage profile by controlling the reactive power using FACTS devices in the IEEE-14 bus system. Initially, we analysed the IEEE-14 bus system under the standard test data. & after that, we have used Static Var Compensation (SVC), and STATCOM was the compensator, and the result is compared for both compensated devices. The Indian electrical structure was generally considered unreliable. The Northern grid had previously collapsed in 2001. An estimated 27% of the power generated was lost in transmission or stolen [5].

Further, about 25% of the population, approximately 300 million, had no electricity. Plans suggested that India remained decades away from having an appropriate energy supply [7]. The July 2012 India blackout was the most significant power outage in history, occurring as two separate events on 30 and 31 July 2012. The outage affected over 620 million people, about 9% of the world population, or half of India's population, spread across 22 states in Northern, Eastern, and Northeast India. An estimated 32 gigawatts of generating ability was taken offline in the outage [6]. It concluded that four factors were responsible for the two days of blackout [8]. Firstly, weak inter-regional power transmission corridors due to multiple existing outages (both scheduled and two forced). Secondly, The 400 kV line on Bina-3, Gwalior-Agra link, is heavily loaded. Thirdly, Inadequate response by State Load Dispatch Centers (SLDCs) to the instructions of Regional Load Dispatch Centers (RLDCs) to reduce overdraws by the Northern Region utilities and underdrawn /excess generation by the Western Region 4utilities. Finally, the 400 kV Bina-Gwalior link is lost due to the misoperation of its protection system. If the weakest link (most sensitive to load changes) were known earlier & by applying some protection schemes, the blackout would have been avoided. Finding a sensitive node in the power system is necessary to avoid the above-said problems.

2. PROBLEM DOMAIN

Voltage stability is the main issue in planning and operating power systems, limiting power transfer. Voltage stability is concerned with the ability of a power system to maintain acceptable voltages at all buses in the system under normal conditions and after being subjected to a disturbance. A power system is set to have entered a state of voltage instability when a disturbance results in a progressive and uncontrollable decline in voltage. Inadequate reactive power support from the generator and transmission line leads to voltage instability or collapse, resulting in several major system failures worldwide. They are South Florida, USA, system disturbance of 17 May 1985, (transient, 4 sec). NREB grid disturbance in India in 1984 and 1987.

2.1 Reactive Power and Voltage Failure

Voltage failure commonly occurs in a power system which is usually heavily loaded, faulted and has reactive power storage. Voltage failure in a system is stable and involves many power system components and variables a once. Indeed, voltage collapse often involves the entire power system through relatively large participation in one particular section of the power system. However, several variables are typically involved. Physical understanding of the nature of voltage collapse may be gained by examining the generation, transmission and consumption (Including surplus and deficit) of reactive power. Lamination on power production includes generator and reactive power compensator limit and the reduced capacity reactive power by the line and fixed capacitor due to low voltage. The primary lamination on the transmission of power is the high reactive power loss on the heavily loaded long transmission line. There may also be outages and reduced transmission capacity. Reactive power demands of load increase with the increase in load, motor stalling or changes in load composition.

Voltage collapse can offer in transient time scale or in long terms time scale. Voltage collapse in the long-term time scale can include effects from the transient scale can include effect from transient time scale; for example, a slow voltage collapse taking several minutes may end in fast voltage failure in the short time scale. Voltage stability and voltage collapse are used somewhat interchangeably by many researchers. Voltage collapse is the process by which the sequence of events accompanying voltage instability leads to an unacceptable voltage profile in significant parts of the power system. It may be manifested in several different ways. Voltage collapse may be characterised as follow: The initiating event may be due to a variety of reasons: small gradual system change such as a natural increase in system load or sudden disturbances such as loss of generating units or a heavily loaded line. Reactive compensation can be made most effective by the judicious choice of a mixture of shunt capacitors, static-var system and possible synchronous condenser.

2.2 Factors Affecting Voltage Stability

It is well known that slower-acting devices such as generator over- excitation limits, the system load characteristics, on-load tap changing and compensation devices contribute to the evolution of voltage collapse. The power system modelling is similar to long-term voltage stability and load flow studies.

Most components can be modelled with the existing model, control of HVDC and static Var compensator. These devices contribute to voltage stability, particularly short-term voltage stability. The analysis and combination of fast and slow-acting devices are complicated with the traditional simulation tool but may be easily analysed with a fast voltage stability analysis method. The different methods obtained by researchers for improving voltage stability can be improved by adopting the following means: (a) Compensating the line length reduces net reactance and power flow increase. (b) HVDC tie may be used between regional grids. Enhancing the localised reactive power support (SVC) is more effective, and capacitor banks are economical. FACTS devices or synchronous condensers may also be used.

2.3 FACTS Devices

An approach to improving voltage profile by controlling reactive power, the rapid development of power electronics technology provides exciting opportunities to develop new power system equipment to utilise the exciting system better. Since 1990, several control devices under the terms FACTS technology have been proposed and implemented. FACTS device can be effectively used for power flow control, load sharing among parallel corridors, voltage regulation, transient stability enhancement and system oscillation mitigation. The advantages of FACTS devices are as follows:

1. Control of power of line flow (both active and reactive), as wanted and within limits, is possible.
2. Fall of voltage drop in power lines is possible. Regulation can be improved.
3. Reduction of r allows more flow of active power in lines.
4. The Loadablity of lines is increased.
5. Voltage stability and voltage security are enhanced.
6. Security of tie lines connecting two sub-grids is increased.
7. Transient stability is increased.
8. Short circuit currents and overloads can be controlled up to certain limits.
9. Generation cost reduces, and Passive compensation requirement reduces.

Static VAR compensator (SVC)

A static VAR compensator (SVC) is an electrical device for providing fast-active reactive power on high-voltage electricity transmission systems. SVCs are part of the FACTS family, regulating voltage and stabilising the system. Disparate a synchronous condenser, a rotating electrical machine in a static VAR compensator, with no significant moving parts (other than internal switchgear). Before the innovation of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks. The SVC is an automated impedance matching device designed to bring the system closer to the unity power factor. SVCs are used in two main situations: (a) Connected to the power system to regulate the transmission voltage (Transmission SVC). (b) Connected near large industrial loads to improve power quality (Industrial SVC)

STATCOM

A power electronics voltage-source converter device used to maintain reactive power within a limit is a static synchronous compensator (STATCOM). This device is used in AC electrical power transmission grids. This device is a member of the FACTS family.

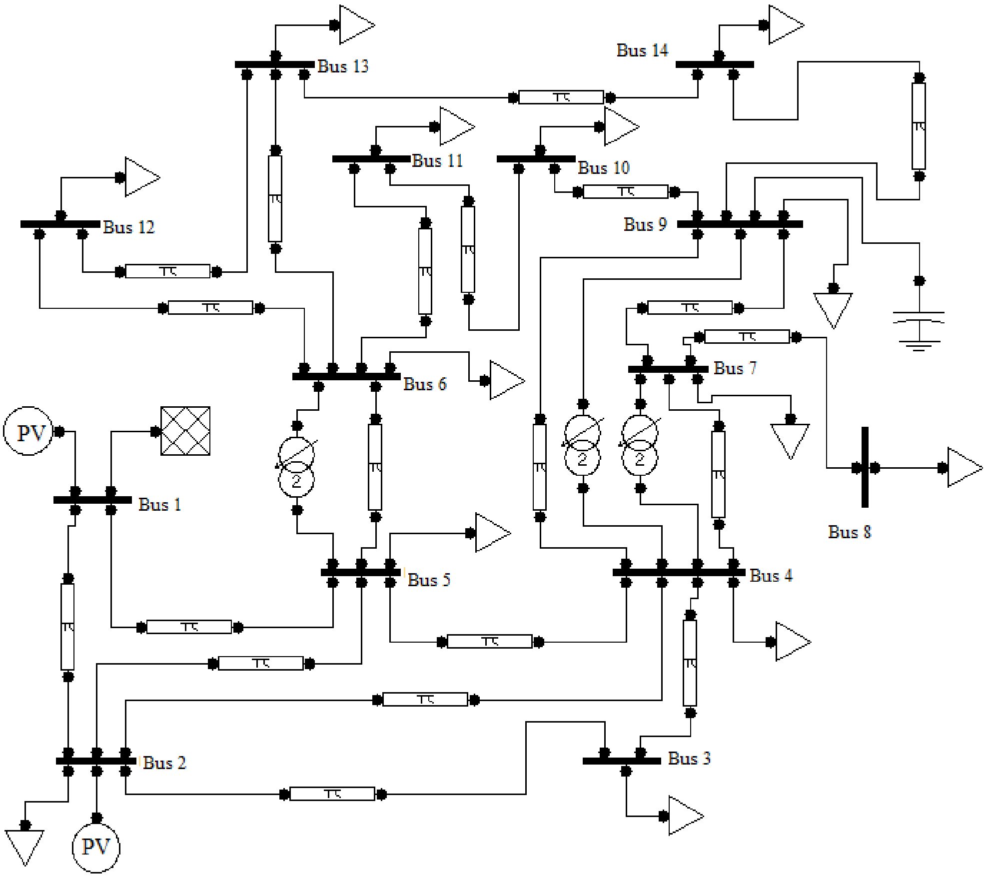

Figure 1. PSAT Model of IEEE-14 bus system

3. METHODOLOGY

An IEEE-14 bus network under study was designed, and parameter values were chosen per the IEEE-14 bus standard shown in Fig.1. The networks were simulated with the help of the Power System Analysis Tool (PSAT) and MATLAB software. In this paper, voltage stability improves by controlling the reactive power or using FACTS devices. In FACTS devices, Static-Var compensation (SVC) and STATCOM improve voltage stability by connecting at the weakest nodes. Under the test network, wind-based distributed generation of 50 MVA and 11kV is connected at bus 14 since it is the weakest bus with the maximum power drop, indicating the increasing trend in the power utility.

After connecting DG, an imbalance was observed in reactive power and to overcome it. A model of the IEEE-14 bus system is being designed & have used. The STATCOM is connected to support the electricity network, which has a poor power factor and voltage regulation, and the most common use is for voltage stability. A STATCOM is simply a voltage source converter (VSC)-based device with a voltage source behind a reactor. The voltage source is formed from a DC capacitor, so a STATCOM has less active power capability. The active power capability may be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the Simulink standard test data for it is shown in figure 1. After feeding the data of table 1, table 2, table 3, and table 4 in the model of the IEEE-14 bus system shown in figure 1, the power flow result of the IEEE-14 bus without SVC and STATCOM by the Newton-Raphson method are obtained as in table 5. Table 6 shows the power flow result of the IEEE-14 bus system with static-var compensation (SVC), and table 7 shows the power flow result of the IEEE-14 bus with STATCOM.

Table 1. The input data for the above model is given below.

B. No.	GENERATION		LOAD	
	REAL (MW)	REACTIVE (MVAR)	REAL (MW)	REACTIVE (MVAR)
1	232.4	-16.9	0	0
2	40	42.4	21.7	12.7
3	0	23.4	94.2	19
4	0	0	47.8	3.9
5	0	0	7.6	1.6
6	0	12.2	11.2	7.5
7	0	0	0	0
8	0	17.4	0	0
9	0	0	29.5	16.6
10	0	0	9	5.8
11	0	0	3.5	1.8
12	0	0	6.1	1.6
13	0	0	13.5	5.8
14	0	0	14.9	5
B. No.:-Bus number				

Table 2. Bus Data

		Line Impedance		HLCS
L.No.	B. No.	R (p.u.)	X (p.u.)	(p.u.)
1	01-Feb	0.01938	0.05917	0.0264
2	02-Mar	0.04699	0.19797	0.0219
3	02-Apr	0.05811	0.17632	0.0187
4	01-May	0.05403	0.22304	0.0246
5	02-May	0.05695	0.17388	0.017
6	03-Apr	0.06701	0.17103	0.0173
7	04-May	0.01335	0.04211	0.0064
8	05-Jun	0	0.25202	0
9	04-Jul	0	0.20912	0
10	07-Jul	0	0.17615	0
11	04-Sep	0	0.55618	0
12	07-Sep	0	0.11001	0
13	09-Oct	0.03181	0.0845	0
14	06-Nov	0.09498	0.1989	0
15	06-Dec	0.12291	0.25581	0
16	Jun-13	0.06615	0.13027	0
17	Sep-14	0.12711	0.27038	0
18	10-Nov	0.08205	0.19207	0
19	Dec-13	0.22092	0.19988	0
20	13-14	0.01709	0.34802	0
L. No.: Line Number, HLCS:- Half line charging susceptance				

Table 3. Line Data

Bus No.	Voltage Magnitude (p.u.)	Reactive Power Limit	
		Minimum MVAR	Maximum MVAR
2	1.045	-40	50
3	1.01	0	40
6	1.07	-6	24
8	1.09	-6	24

Table 4. Regulated Bus Data

Transformer	B/W Buses	Tap-Setting
1	4-7	0.978
2	4-9	0.969
3	5-6	0.932

Table 5. Power flow result of IEEE-14 bus without SVC and STATCOM

Bus No.	Voltage (p.u.)	Phase (rad)	P.Gen (p.u.)	Q.Gen (p.u.)	P.load (p.u.)	Q.load (p.u.)
1	1.06	0	1.0279	0.0812	0	0
2	1.045	-0.0359	0.4	0.1986	0.217	0.127
3	1.01	-0.1047	0.4	0.0613	0.942	0.19
4	1.0232	-0.0795	0	0	0.478	0.039
5	1.0273	-0.065	0	0	0.076	0.016
6	1.07	-0.0846	0.4	0.1255	0.112	0.075
7	1.0532	-0.069	0	0	0	0
8	1.09	-0.0076	0.4	0.2399	0	0
9	1.0359	-0.1038	0	0	0.295	0.166
10	1.0342	-0.1053	0	0	0.09	0.058
11	1.0482	-0.0971	0	0	0.035	0.018
12	1.0538	-0.1002	0	0	0.061	0.016
13	1.0473	-0.1018	0	0	0.135	0.058
14	1.0226	-0.1208	0	0	0.149	0.05

Table 6. Power flow result of IEEE-14 bus with SVC

B. No.	Voltage (p.u.)	Phase (rad)	P.Genn (p. u.)	Q.Gen (p.u.)	P.load (p.u.)	Q.load (p.u.)
1	1.06	0	1.028	0.07144	0	0
2	1.045	-0.03586	0.4	0.16498	0.217	0.127
3	1.01	-0.10455	0.4	0.04075	0.942	0.19
4	1.0266	-0.08066	0	0	0.478	0.039
5	1.0296	-0.0654	0	0	0.076	0.016
6	1.07	-0.08186	0.4	0.03775	0.112	0.075
7	1.0644	-0.07199	0	0	0	0
8	1.09	-0.01122	0.4	0.17031	0	0
9	1.0581	-0.10654	0	0	0.295	-0.04674
10	1.0527	-0.1072	0	0	0.09	0.058
11	1.0576	-0.09694	0	0	0.035	0.018
12	1.0555	-0.0976	0	0	0.061	0.016
13	1.0506	-0.09992	0	0	0.135	0.058
14	1.0368	-0.1211	0	0	0.149	0.05

Table-7. Power flow result of IEEE-14 bus with DG and STATCOM

Bus	V [p.u]	Phase [rad]	P. gen [p.u]	Q. gen [p.u]	P. load [p.u]	Q. load [p.u]
Bus 1	1	0	0.13034	-0.24155	0	0
Bus 2	1	-0.00517	0.01883	-0.71067	0.01022	0.00598
Bus 3	1.0281	-0.01961	0	0	0.04435	0.00899
Bus 4	1.0557	-0.0287	0	0	0.0225	0.00184
Bus 5	1.0454	-0.02205	0	0	0.00358	0.00075
Bus 6	1.0273	-0.0206	0	0	0.00527	0.00353
Bus 7	1.0708	-0.03305	0	0	0	0
Bus 8	1.0709	-0.03305	0	0	0	0
Bus 9	1.1007	-0.0366	0	-0.000005	0.01389	-1.103
Bus 10	1.0876	-0.03487	0	0	0.00424	0.00273
Bus 11	1.058	-0.02888	0	0	0.00165	0.00085
Bus 12	1.0323	-0.02185	0	0	0.00287	0.00075
Bus 13	1.0372	-0.02438	0	0	0.00636	0.00273
Bus 14	1.0724	-0.03256	0	0	0.00702	0.00235

Table-8. 14 bus integrated system results without SVC and STATCOM for varied reactive load

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14
Original Power Flow Result	1.06	1.045	1.01	1.0232	1.0272	1.07	1.0532	1.09	1.0359	1.0342	1.0482	1.0538	1.0473	1.0226
SET1 (5% CHANGE)	1.06	1.045	1.01	1.0228	1.0271	1.07	1.0525	1.09	1.0344	1.0328	1.0474	1.0534	1.0467	1.0211
SET2 (10% CHANGE)	1.06	1.045	1.01	1.0225	1.0269	1.07	1.0517	1.09	1.033	1.0314	1.0466	1.053	1.0461	1.0197
SET3 (15% CHANGE)	1.06	1.045	1.01	1.0222	1.0267	1.07	1.0509	1.09	1.0315	1.0299	1.0457	1.0526	1.0455	1.0182
SET4 (20% CHANGE)	1.06	1.045	1.01	1.0219	1.0264	1.07	1.0502	1.09	1.0301	1.0285	1.0449	1.0522	1.0449	1.0167
SET5 (25% CHANGE)	1.06	1.045	1.01	1.0216	1.0262	1.07	1.0494	1.09	1.0286	1.027	1.0441	1.0517	1.0443	1.0152
SET6 (30% CHANGE)	1.06	1.045	1.01	1.0212	1.026	1.07	1.0487	1.09	1.0271	1.0256	1.0433	1.0513	1.0438	1.0137
SET7 (35% CHANGE)	1.06	1.045	1.01	1.0209	1.0257	1.07	1.0479	1.09	1.0256	1.0241	1.0425	1.0509	1.0432	1.0122
SET8 (40% CHANGE)	1.06	1.045	1.01	1.0206	1.0255	1.07	1.0471	1.09	1.0242	1.0227	1.0416	1.0505	1.0426	1.0107
AVERAGE	1.06	1.045	1.01	1.0212	1.0264	1.07	1.0502	1.09	1.03	1.0285	1.0449	1.0522	1.045	1.0167
DIFFERENC E	0	0	0	0.002	0.0008	0	0.003	0	0.0059	0.0057	0.0033	0.0016	0.0028	0.0059

4. RESULT AND DISCUSSION

It compares the results obtained in Tables 5, 6 & 7, i.e. power flow results of IEEE – 14 bus systems with and without SVC. We found out that there were several changes in voltage profiles, reactive power generation & its compensation on various buses, which are given below are Voltage profiles of bus no: 4, 5, 7, 9, 10, 11, 12, 13, and 14 have improved. Reactive power generation at buses no 1, 2, 3, 6 & 8 has been improved. Reactive power has been compensated at bus no 9.

We changed the reactive load data from 5% to 40%, connected at bus numbers 2, 3, 4, 5,6,9,10,12, 13 and 14, respectively. The result obtained is tabulated at the last Table 8. Here the main focus is on the voltage profile. From the table, we can note that bus numbers 9 & 14 are undergoing maximum changes in reactive power. Hence, from the above, we have concluded that we have to connect SVC and STATCOM at the bus no 9 & 14. But, after connecting them at bus number 9 and then on bus number 14, it was observed that the power flow results of the system were improved when we connected SVC, DG and STATCOM at bus number 9 (the result given in table 7). as compared to bus number 14. Hence, we have worked on bus number 9 of the IEEE – 14 bus system.

5. CONCLUSION

From table 6 and table 7, it is clear that the voltage profile is weak at bus 9 & bus 14 when subjected to percentage changes in load, which may result in voltage collapse. Hence a special protection scheme can be applied to these buses to prevent voltage collapse. For this reason, we have found that facts devices are beneficial to improving voltage stability, but out of them, STATCOM is more valuable because STACOM can inject and compensate reactive power.

REFERENCES

[1]. S. P. Rajaram, V. Rajasekaran, and V. Sivakumar, “Optimal Placement of Distributed Generation for Voltage Stability Improvement and Loss Reduction in Distribution Network,” IJIRSET, vol. 3, no. 3, pp.529-543, Mar. 2014.

[2]. Sanjib Ganguly, Dipanjan Samajpati, “Distributed Generation Allocation on Radial Distribution Networks under Uncertainties of Load and Generation Using Genetic Algorithm,”

[3]. IEEE Transaction on Sustainable Energy, vol.6, no.3, pp. 688-697, July 2015.

[4]. Ali Azizivahed, Ehsan Naderi, Hossein Narimani, Mehdi Fathi, and Mohammad Rasoul Narimani, "A New Bi-Objective Approach to Energy Management in Distribution Networks with Energy Storage Systems," IEEE Transaction on Sustainable Energy, vol.9, no.6, pp. 56-64, Jan 2018.

[5]. Donal Caples, Serato Boljevic, and Michael F. Conlon, "Impact of Distributed Generation on Voltage Profile in 38kV Distribution System," in Proc. 8th Int. Conf. on the European Energy Market, Zagreb, Croatia, May 2011, pp. 532-536.

[6]. Thomas Ackermann, Goran Andersson, and Lennart Soder, "Distributed Generation: a definition," ELSEVIER Electric Power Systems Research, vol. 57, pp.195-204, Dec. 2000.

[7]. Rangan Banerjee, "Comparision of options for distributed generation in India," ELSEVIER Energy Policy, vol. 34, pp. 101-111, Jul. 2004.

[8]. Pathomthat Chiradeja, and R. Ramakumar, "An Approach to Quantify the Technical Benefits of Distributed Generation," IEEE Trans. Energy Conv. vol. 19, no. 4, pp. 764-773, Dec. 2004.

[9]. Naresh Acharya, Pukar Mahat, and N. Mithulananthan, "An analytical approach for DG allocation in the primary distribution network," ELSEVIER Electrical Power and Energy Syst., vol. 28, pp. 669-678, Feb. 2006.

[10]. J.A. Pecas Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins, "Integrating Distributed Generation into electric power systems: A review of drivers, challenges and opportunities," ELSEVIER Electric Power Syst. Research, vol. 77, pp. 1189-1203, Oct. 2006.

[11]. Yanhua Liu and Yongning Chi, Weisheng Wang and Huizhu Dai, "Impact of large scale wind farm integration on power system transient stability," in 2011 4th International Conference on Electric Utility Deregulation and Restructuring and Power Technologies, pp. 1301-1305, 2011.

[12]. O.L.BEKARI, M.K.FELLAH,"Theory ,Modelling and Control of FACTS devices "conference JENEA2006 JUOMEES joumees Nationalesd' Electrotechnique et d'Automatique At oran Algeria,November-2006

[13]. Mahdiyeh Eslami, Hussain SHARIFF, Azah MOHAMED, Mohammad KHAJEHZA DEH "A Survey on Flexible AC Transmission System (FACTS)" PREGLAD ELEKTROTECHNICZNY (Electrical Review) R88NR, Jan 2012.