Voltage Control Improvement in Electrical Power Distribution Systems Using Solar Resources

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September 23, 2022

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Abstract: *Usage of distributed generation systems is increasing. One advantage of using distributed generation system is the stability of distribution network voltage. A distributed generation resource is photovoltaic systems. Photovoltaic systems are used along with energy storage component and incident angel tracer to be able to inject a monotonic flow of power into network. In this paper, the photovoltaic system is used without the mentioned equipment's. To evaluate the effect of this system upon network voltage, a sample 33-bus network is introduced and the photovoltaic system is used on bus 18. The results have shown that if the radiation angel tracer is not used, then voltage of the bus on which the photovoltaic system has been installed reaches 0.986 near noon. Before sunrise and after sunset, when there is no sun rays, this bus voltage reaches 0.948 indicating 4% of changes in the bus voltage.*

Keywords: *Voltage Control, Renewable Energies, Distribution Networks, Distributed Generation, Photovoltaic(PV).*

1. INTRODUCTION

According to environmental pollution of fossil resources and inability of the mentioned resources to produce enough electricity, countries are looking for new energy resources to meet their energy requirements. One of these renewable energy sources is the famous solar energy. Sun is a major energy resource and acts as the origin of life. It is the mother of other energy resources. According to scientific estimation, sun was born 6000 million years ago 4/2 million tons of sun mass per second convert into energy. This hot globe is considered as a huge energy resource for 5 billion years. In traditional systems, electricity production was a concentrated process. The generated power was transmitted to charge centers via transmission systems and then discharged to consumer places by distribution systems. In these systems, new lines, transformers and stations are installed in order to meet customers' need [1] . Due to low level of voltage, high level of current in distribution system and the wideness of the mentioned current, the major part of system loss is related to distribution network. On the other hand, immediate communication between distribution network and end users leads to greater reliability [2].This motivates engineers and researchers to optimize and reduce the loss of distribution network. There are multiple ways to mitigate the loss of distribution network [3,4] . Majority of the methods including reactive power control using a capacitor need the installation of new equipment's. Another method is to use distributed generation resources in distribution networks. Using distributed generation resources not only reduces the distribution network loss but covers the increasing demand. An replacement method to deal with the mentioned problem is to use local power generation using distributed resources. Distributed generation improves requirements of generation capacity, power transmission and distribution networks. It also eliminates the need for installing new lines and stations [5,6] .Different terms are used in various papers to name the distributed generation which lead to confusion. Actually, all terms have the same meaning. A general definition for distributed generation is as below: distributed generation is a power resource which is connected to distribution network directly [7,8]. Generally, distributed generation is able to Best of coordination in various applications such as sources of backup or emergency, loads peak, Production fractional and Overall supply of load demand. Therefore, optimal replacement of distributed generation provides some advantages including loss reduction, reliability improvement of system, more capacity for distribution and transmission, Delaying the need for network reconstruction and drop voltage reduction in buses. In this paper, the effects of photovoltaic systems as distributed generation resources upon voltage stability in buses is examined [9].

2. SOLAR ENERGY

Sun is very huge natural nuclear reactor in which substances convert into energy due to infusion. Each day, 350 billion tons of its mass convert into light. The internal temperature of sun is 15 million degrees centigrade. The energy is provided for us in the form of visible, infrared and ultraviolet spectra amounts 1 kw/m^2. Sun is similar to a gigantic firing globe as 100 times as earth in magnitude. The mentioned star includes hydrogen and helium. The mentioned gases make a big combustion and produce severe rays of light and heat. These rays travel toward the earth. On the way toward the earth, one-third of rays scatter into space and the remaining reach the earth as heat and light. It is known that light speed is 300000km/s. on the other hand, it takes 8 minutes for solar rays to reach the earth. Therefore, it is possible to calculate the distance between the earth and sun. On this long distance, a huge amount of solar heat and energy waste away. But, the remaining amount reaching the earth is enough to keep creatures alive and provide them with a suitable habitat. The most important features of solar energy are solar energy is endless, it is a clean resource, it doesn't make any damages to environment and it is easy to automation it, it is possible to design its capacity according to demands [10,11].

3. PHOTOVOLTAIC SYSTEMS

According to increasing population and more energy demand and consumption, sun is considered as a ubiquitous and cheap major energy resource. In this section, solar panels and photovoltaic systems are introduced. Bing located in a proper place; these panels absorb solar energy and convert it into electricity. As a matter of fact, these panels are composed of silicon cells [12]. When they expose to solar rays, electron movement is caused due to some interactions inside the panels and then DC load flows at the outlet of cells. Photovoltaic system is one of the most used samples of new energy applications. Up to now, multiple systems with different capacities from 0.5 watt to some megawatts have been introduced and installed worldwide. According to reliability and applicability, the number of these systems is increasing. Therefore, various studies on photovoltaic systems have been conducted recently.

Photovoltaic includes two words: photo, a Greek word, indicating light and voltaic indicating electricity. Accordingly, photovoltaic points to light-based electricity. A phenomenon to produce electricity using incident light without actuator mechanism is called photovoltaic phenomenon. Every system using the mentioned phenomenon is referred as photovoltaic system. The panel converting solar energy into electricity is called solar panel or battery. Solar panels are composed of silicon. According to increasing population and more energy demand and consumption, sun is considered as the only ubiquitous energy resource. Components of photovoltaic system are solar panels, modules, arrays, voltage regulators and controllers, storage batteries for electrical energy. To achieve desirable voltage and current, cell with different arrays are attached together as a module, figure 1. Modules are installed on a metal plate or frame (usually aluminum) and make the photovoltaic panel or plate [13].

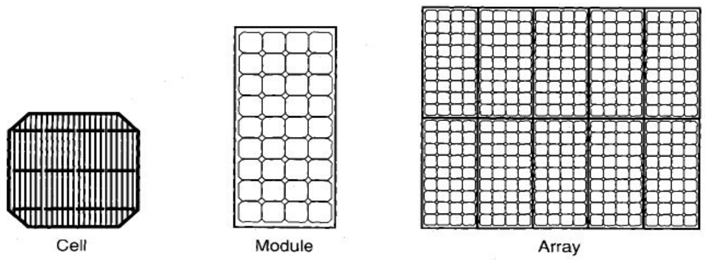

Figure 1. Cell, module and PV array

According to the figure 2, it is possible to obtain desirable voltage and current by making series or shunt arrays of cells. Series cells provide higher voltage but the shunt ones are able to produce higher current. Figure 3 shows cells, modules and Arrays and how they are placed together [14].

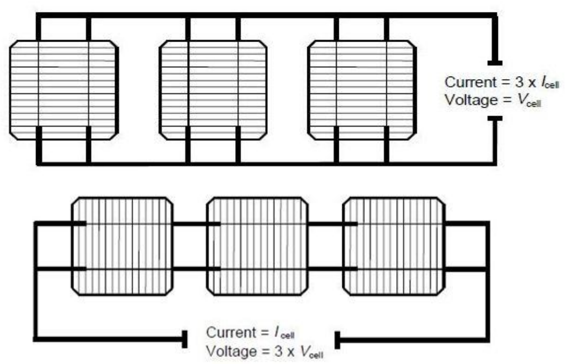

Figure 2.Series And Shunt Electrical Connection of Cells

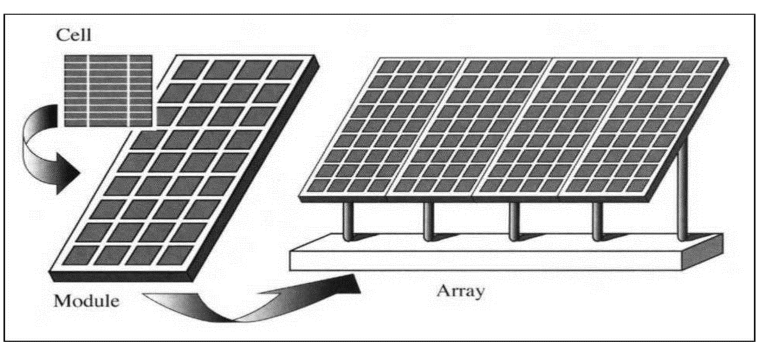

Figure 3. Cells, Modules and Arrays and How They Are Placed Together

3.1. Voltage Regulation And System Control

Due to the fact that the electricity generated by PV arrays is of direct current type, so it is necessary to convert the output to AC power with voltage, frequency and phase suitable for connection to the mains or local load. This is done by a device called an inverter [15,16]. If the intensity of solar radiation changes at ambient temperature, the output voltage of the PV arrays also changes. Therefore, in systems that have battery storage, it is necessary to adjust the output voltage of the arrays to prevent the battery from overcharging. In this case, a converter is used (Figure 4).

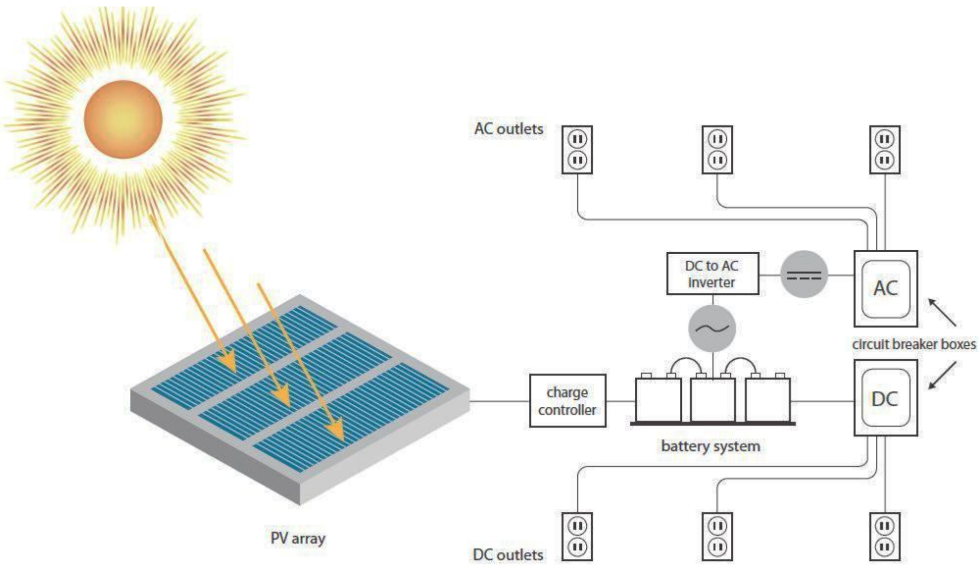

Figure 4. How to Connect Arrays to the Consumer and the Battery Bank

3.2. Advantages and Disadvantages of Photovoltaic Systems

The most important advantages of photovoltaic systems are no need for fossil fuels, environment protection, pollution reduction, long life cycle, great reliability due to lack of mechanical portable parts, less danger such as fire or explosion, ease of installation and operation, no need for complicated equipment's and human labor, ability to change the power according to increase or decrease of capacity in photovoltaic systems (by increasing or decreasing the number of modules). The primary disadvantage is the astronomical price. Although the price of photovoltaic systems is decreasing due to developing technology, but it is necessary to evaluate the economics of resources. Economical studies on renewable systems have shown that despite the great investment required to produce electricity, the final price of electricity transmitted to places far from basic network is economical. Photovoltaic systems include three parts: independent, dependent, hybrid. Dependent systems inject electrical energy produced by solar panels into global network directly. Importance of these systems is so high that power plants with capacity of more than multiple megawatts have been installed using the mentioned systems [17]. Voltage dip compensation of transmission line is a main feature of these systems. Regarding the effect on power system, power coefficient of photovoltaic generation units is about 1. Investigations show that in some cases, presence of at least 10% of power generation of the mentioned units prevents usage of capacitors in systems in order to correction voltage profiles. Figure. 5 shows diagram of photovoltaic system connected to the network which feeding AC and DC loads [18].

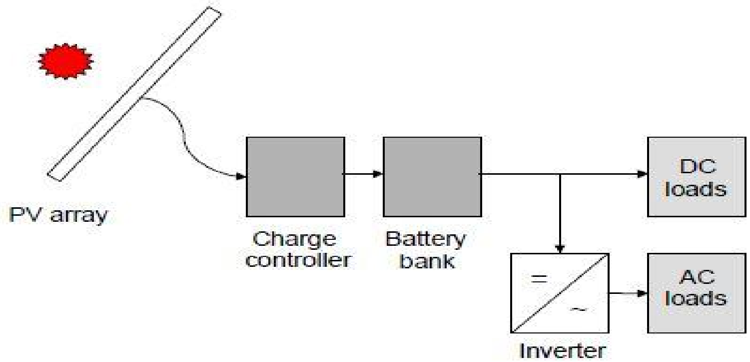

Figure 5. Photovoltaic System Connected to the Network

3.3. Characteristic Power of Two Moving and Fixed Arrays During Day

Among two moving and constant photovoltaic arrays, the moving solar array produces more power due to direct sun light on the array. But, constant array exposes to skewed light [19] . In figure 6, voltage-current curves of moving and constant photovoltaic arrays is shown.

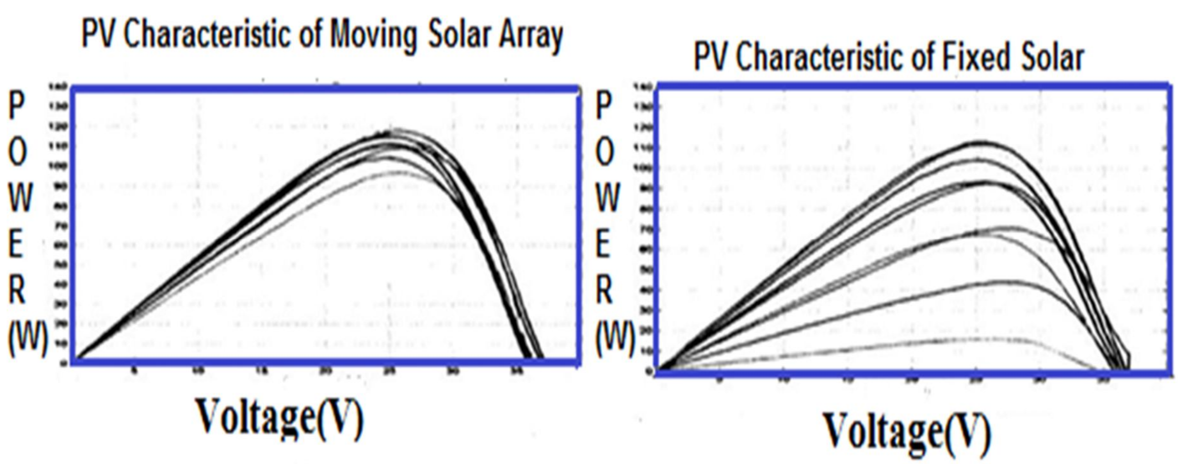

Figure 6. Voltage-Current Curves of Moving and Fixed PV Arrays during a Day

3.4. Hybrid Systems

Hybrid systems are systems that use multiple power supplies to supply the required electrical energy. And the PV system is one of the main power sources. Other energy sources used in this complex include the national grid, diesel generators, wind turbines, and so on. (In this model, based on the situation and the need for load, the use of each of these power supplies is prioritized and controlled) . In hybrid systems, multiple power sources are used and in case of interruption of any other source. In this model, the possibility of power outage is minimized (Figure 7) [19].

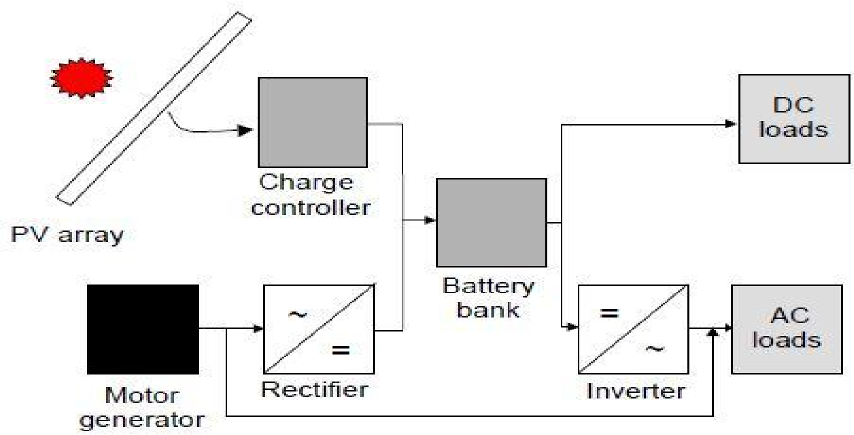

Figure 7. Diagram of a Hybrid PV system combined with a Diesel Generator

4. Review on Power Distribution Networks

Power distribution is the last step of power chain. It is considered as receiving power from generation stage or transmission with a certain voltage and converting it into the voltage demanded by consumers and power demand via distribution networks of power distribution stations with high voltages(63,132,230,400kv) of transmission lines received and by power transformers reduced it's voltage as primary feeders (20kv). Delivering electricity to consumer places is done by using the 63 or 132 kv lines in distribution networks. primary distribution feeders are responsible for delivering electricity power from main stations into distribution transformers via medium voltage lines. Most medium voltage networks are of 20 kv in Iran. But, 11 and 33 kv networks are also used in limited applications. Distribution transformers are of two kinds: aerial and ground. The mentioned transformers reduce voltage level up to 380 volts which is related to secondary circuits. Secondary distribution systems include reducing distribution transformers, secondary circuits, branches for meeting electricity demands and certain tools to measure the amount of electricity consumed by consumers. Generally, distribution systems for houses are of single-phase type but for commercial and industrial consumers, three-phase systems are used. Two-phase systems are used rarely. There is a direct communication between distribution systems and users. Accordingly, these systems have to accustom to variable conditions during various periods of time due to season alternating. Sometimes, some problems are caused such as technical obstacles, overload of ultra-distribution stations, voltage reduction in distribution stations, extra current in 20 kv feeders and imbalance of charge. On the other hand, increasing the number of subscribers leads to multiple problems especially when the newcomers increase the load of network. Due to change of load in distribution systems, system loss is variable and also changes the voltage level and feeder current [20].

5. Simulation and Results

In this paper, to investigate the effect of photovoltaic systems on distribution system voltage stability, IEEE 13-bus and IEEE 33-bus networks are used.

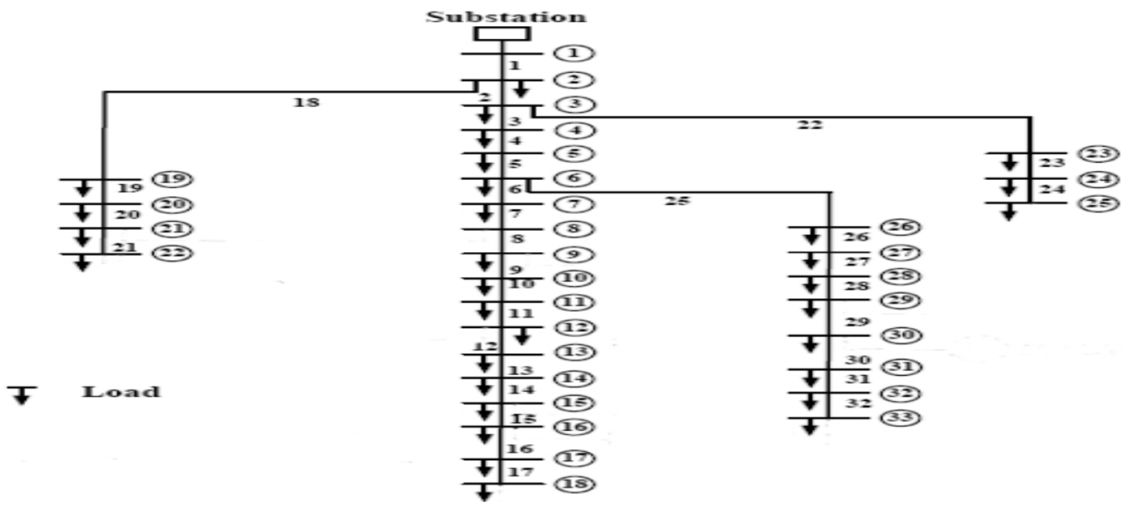

Figure 8. IEEE 33-Bus Test Network

It is assumed that a photovoltaic system with maximum power of 120 kv is attached to bus 18. Output of photovoltaic system during a day is presented in table 1.Characteristics this network Including loads power and impedance of lines shown in Table 2 and Table 3 in the Appendix.

TABLE 1: Power output of PV systems at different hours

Power output of PV systems(Kw)	Time (S)
73	9:00
94	10:00
106.5	11:00
113	12:00
115.2	13:00
110.3	14:00
95.5	15:00
69.2	16:00
45	17:00
16.2	18:00

As mentioned before, to the Increase the efficiency of photovoltaic systems, radiation Angle tracer installed on the panels is used. Changing the angel of panel, maximum power is obtained since sunrise to sunset. In this study; it is assumed that such system has not been installed on the panel. Changes of the buses on which photovoltaic system is installed are shown in figure 9. According to given figure, voltage of bus 18 reaches 0.986 at noon. But, before sunrise and after sunset when there is no sunshine, the mentioned value is about 0.948 indicating 4% changes in this bus voltage.

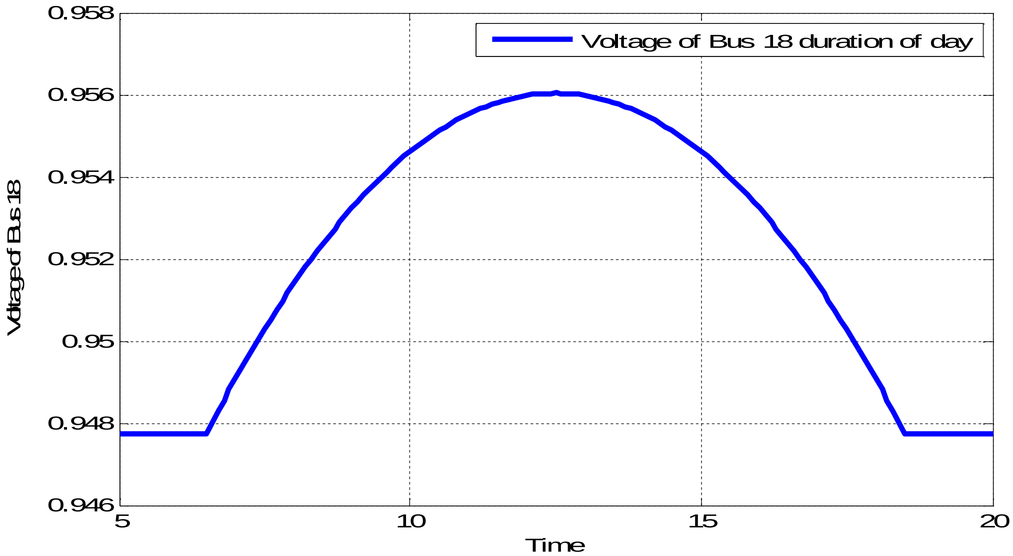

Figure 9. Voltage Change of Bus 18 During Day

To evaluate the effect of generative power level change of photovoltaic system upon voltage of other buses, voltage levels of 33 buses are investigated for two different times: 6 a.m (there is no sunshine) and 12 noon (maximum amount of sunshine). The related values are represented in figure 10.

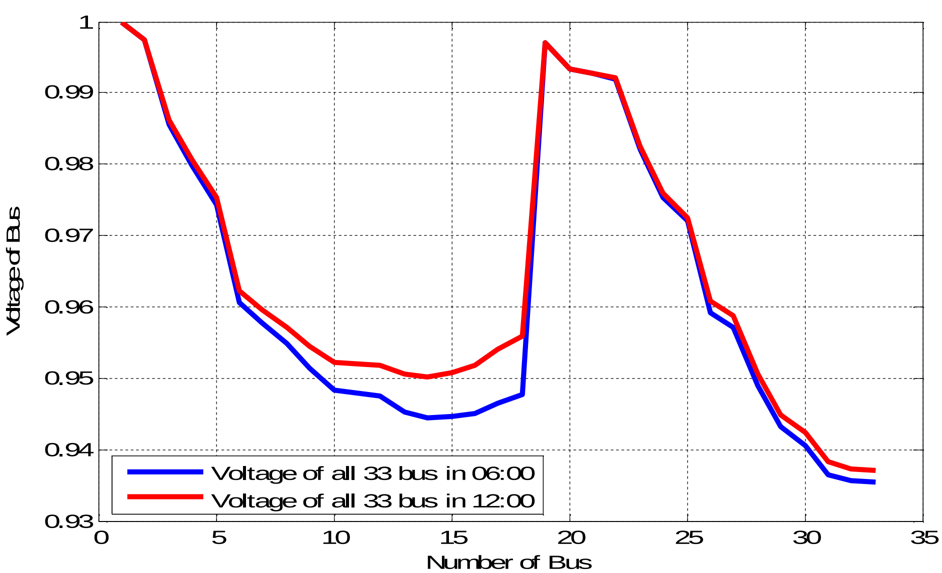

Figure 10. Buses Voltage of Distribution Network For Two Different Times During a Day

6. CONCLUSION AND RECCOMENDATION

In this paper, photovoltaic systems are under study. Advantages, disadvantages, technology of solar cells, components of photovoltaic systems, various types including independent, dependent and hybrid and also characteristic output of a sample panel during a day are discussed. Finally, IEEE 33-bus network is considered and a photovoltaic system is installed on a bus of network. Then, the effect of incident light on bus voltage is examined. The results of simulation done by MATLAB indicate promotion of voltage control in the considered network. At last, it is recommended to use FACTS devices in addition to distributed generation systems. Using an algorithm such as PSO, the two mentioned systems are coordinated in order to have both power active and reactive generation. As the last step, the effect of this coordination on the bus voltage and network loss is investigated.

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Appendix

TABLE 2: Network Loads Power

Reactive Power (KVAR)	Active Power (KW)	Bus No.
0	0	1
60	100	2
40	90	3
80	120	4
30	60	5
20	60	6
100	200	7
100	200	8
20	60	9
20	60	10
30	45	11
35	60	12
35	60	13
80	120	14
10	60	15
20	60	16
20	60	17
40	90	18
40	90	19
40	90	20
40	90	21
40	90	22
50	90	23
200	420	24
200	420	25
25	60	26
25	60	27
20	60	28
70	120	29
100	200	30
70	150	31
100	210	32
40	60	33

TABLE 3: Network Feeders Impedance

Inductive Resistance	Resistance (ohm)	Line No.	To the Bus	From the Bus
0.047	0.0922	1	2	1
0.2512	0.493	2	3	2
0.1864	0.3661	3	4	3
0.1941	0.3811	4	5	4
0.707	0.819	5	6	5
0.6188	0.1872	6	7	6
0.2351	0.7115	7	8	7
0.74	1.0299	8	9	8
0.74	1.044	9	10	9
0.0651	0.1967	10	11	10
0.1298	0.3744	11	12	11
1.1549	1.468	12	13	12
0.7129	0.5416	13	14	13
0.526	0.5909	14	15	14
0.5449	0.7462	15	16	15
1.721	1.2889	16	17	16
0.5739	0.732	17	18	17
0.1569	0.164	18	19	2
1.3555	1.5042	19	20	19
0.4784	0.4095	20	21	20
0.9373	0.7089	21	22	21
0.3084	0.4512	22	23	3
0.7091	0.898	23	24	23
0.7071	0.8959	24	25	24
0.1034	0.2031	25	26	6
0.1447	0.2842	26	27	26
0.9338	1.0589	27	28	27
0.7006	0.8043	28	29	28
0.2585	0.5074	29	30	29
0.9629	0.9745	30	31	30
0.3619	0.3105	31	32	31
0.5302	0.3411	32	33	32