International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2012 | Issue 10 | Volume 4 | Number 1 | Pages 91-96

SIMULATION AND IMPROVEMENT OF OPERATION OF DG SYSTEMS CONNECTED TO POWER SYSTEM

F. Fattahi [1,2] **A.M. Hashimov** [2] **N.M. Tabatabaei** [3,4] **S. Guliyeva** [2]

1. Azarbaijan Higher Education and Research Complex, Tabriz, Iran, fattahi1340@yahoo.com
2. Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan, arif@physics.ab.az
3. Electrical Engineering Department, Seraj Higher Education Institute, Tabriz, Iran, n.m.tabatabaei@gmail.com
4. Electrical Engineering Department, Faculty of Electrical and Electronic Engineering, Istanbul Technical University, Maslak, Istanbul, Turkey

Abstract- In this paper, generation system of combined and hybrid wind/PV system has been designed. It is supposed that we are going to minimize the annual cast of stand-alone system during recent 20 years. There are certainty factors in this paper, which can reach to favorable designing by using them. Also the type of used inverter and the best choice of battery in order to have the favorite system have been discussed. The main aim using of Simulink is that suitable for control process and compensator designing, which the hybrid control system is presented for a part of Iran electrical network of Iran.

Keywords: Improvement, Power System, Simulation, DG, PV.

I. INTRODUCTION

As human and different industrial society expands, demand for energy sources is increasing too. On the other hands, fossil sources are about to finish. These sources from the point view of the quantity are limited and also they pollute the environment. Thus, in recent years tending to use new and renewable energy sources has been increased. Wind and solar energies are the most certain available energies for remote and rural regions [1-3].

Predictions of power generation of wind and solar cells are very difficult, because they seriously depend on climate changes. But using hybrid system can be a suitable way to reach economical solutions against costs. On the other hands, we can use power-saving energies, such as batteries to decrease or even get rid of power fluctuations. The suitable sizing for power-saving system depends on the amount of power generation and loads. Here, the hybrid wind/PV/battery system for some special parts of Iran electric company has been discussed [4-6].

II. HYBRID SYSTEM PV/WIND

The system used in this paper consists of three main power wind turbines, solar and saving batteries, which complete each other in hybrid system and supply the loads in certainty condition.

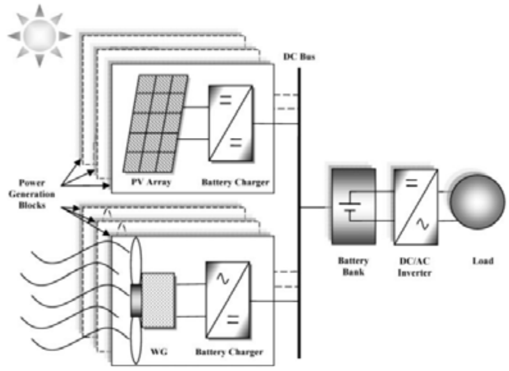

Figure 1. Block diagram of a hybrid wind and PV systems

A. PV Unit Modeling

The PV system consists of PV modules, which are connected to each other in parallel and series. Parallel and series resistance are indicators of loss related to semiconductor and connection structure. If the parallel resistance is too big, it can be ignored output of solar cells according to intensity of sun radiation is calculated by following equation [7-11].

$$P_{pv} = \frac{G}{1000} \times P_{pv.rated} \times \eta_{mppt} \quad (1)$$

whenever vertical and horizontal radiation of sum is possible, vertical radiation is obtained from below equation:

$$G(t.\theta_{pv}) = G_v(t)\cos(\theta_{pv}) + G_H(t)\sin\theta_{pv} \quad (2)$$

G is defined as vertical and horizontal radiation in cell's surfaces (W/M^2), P_{pv} stands for rated power per each cell in G=1000 and η_{mppt} is the DC/DC converter efficiency.

In electrical MPPT analysis mode, the most power of solar system is obtained by open-circuit voltage. The practical way of calculating favorite operation voltage of system and PV open-circuit voltage is following equation [12, 13]:

$$V_{oc} = \frac{K_T}{q} \ln\left[\frac{I_{SC}}{I_0} + 1\right] \quad (3)$$

where K_T is co-efficient of sun cell materials.

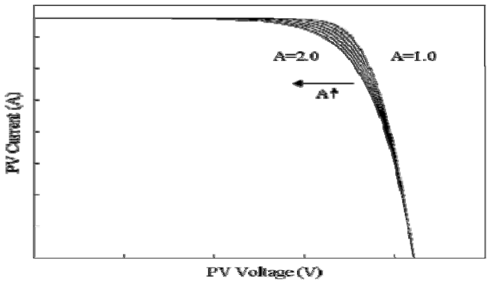

Figure 2. *V-I* characteristic for different areas

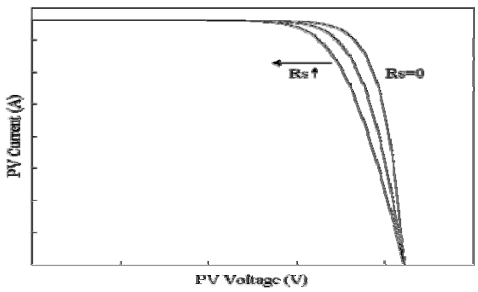

Figure 3. *V-I* characteristic for different R_S

The photo voltaic system shows an inherent non-leaner equation. The MPPT control is done by power electronic devices such as: DC/DC chopper or DC/AC inverter which is put between cell and electrical load, obtain favorite characters.

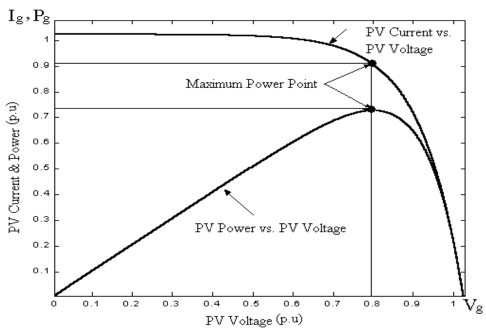

Figure 4. The maximum amount of MPPT

B. Wind Unit Modeling

Output energy of wind turbine can be obtained from power-speed graph, which is illustrated by manufacturer. Wind turbine, by considering wind speed, is calculated by following equation: The wind turbine power relations are as the following:

$$P_{WG} = \begin{cases} 0 & v_\omega \le v_{cc}, v_\omega \ge v_{co} \\ P_{WG_{\max}} \times \left(\dfrac{V_m - V_{ci}}{V_r - V_{ci}} \right)^m & v_{ci} \le v_\omega \le v_r \\ P_{WG_{\max}} + \dfrac{P_f - P_{WG_{\max}}}{V_{co} - V_r} \times (V_\omega - V_r) & v_r \le v_\omega \le v_f \end{cases} \quad (4)$$

Generally, to obtain speed in difficult heights, the Equation (5) is used. Table 1 shows information about Excel-R-BWG wind turbine, which is used in this paper.

$$V_\omega = v_\omega^{measure} \times \left(\frac{h_{hub}}{h_{measre}}\right)^Q \quad (5)$$

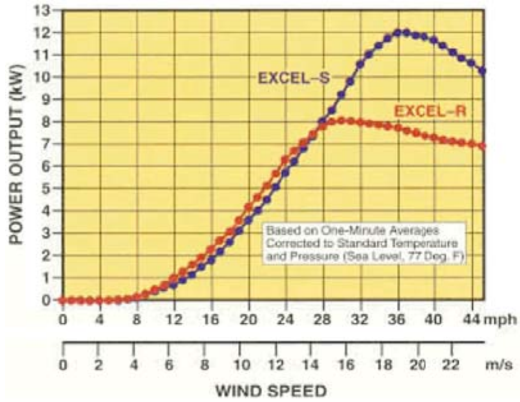

Figure 5. BWG excel-R power-speed

Table 1. Technical information of wind turbines

Wind Generator Specifications	
Rated Power Output	7,500 watts at 29 mph (13.0 m/s)
Cut-in Wind Speed	7.0 mph (3.1 m/s)
Start-up Wind Speed	7.5 mph (3.4 m/s)
Cut-out wind Speed	none
Furling Wind Speed	35 mph (15.6 m/s)
Maximum Design Wind Speed	120 mph (53.6 m/s)
Type	3 Blade Upwind
Rotor Diameter	23.0 ft (7.0 m)
Weight	1050 lbs (477 kg)
Gearbox/Belts	none, direct drive
Temperature Range	-40C to +60C
Generator	Permanent Magnet Alternator
Turbine Output Form	3 phase AC, variable frequency
System Output Form	120VDC, 240VDC, 48VDC nominal (with included battery charge controller)

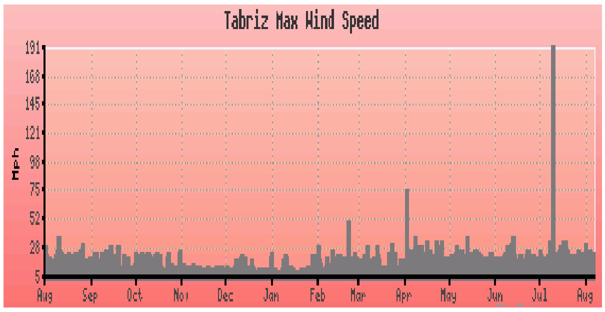

Figure 6. Tabriz wind speed per year

C. Battery

Energy saving can minimize the fluctuation of wind and sun energy. In fact, energy saving batteries can be supposed an intervener between demanded sources to make balance. The type of battery used in this system is DEEP CYCLE, which has two types.

Flooded batteries use fluid electrolyte and sealed battery which are non-fluid electrolyte. In this paper AGM, sealed battery has been selected because they don't need any maintenance, which is one of the important factors in remote zones. Other factors are people life and unskilled persons in maintenance and monitoring using operator to maintain and control the battery during the weak will need a lot of money. In addition, these batteries are the cheapest. Although this kind of battery isn't as well as other such lithium batteries but, because power in these areas is not as critical as other, there is no need to increase the costs.

Next stage is the calculating the size of battery, which can be obtained by doing following steps:
- Calculating total watt-hour for each day by devices;
- Division of total watt-hour in each day by 0.85 to get battery loss;
- Division (2) by 0.6 to get discharge deep;
- Division (3) by rated voltage of battery.

Multiplication (4) by the number of day, battery used (number of days which systems need to operate without any output from PV and wind turbine) equals to

$$= \frac{\text{hours used by load during each day - sum of total watt}}{0.85 \times 0.6 \times \text{rated voltage of battery}} \times \qquad (6)$$
$$\times \text{days used of battery}$$

D. Inverter

Inverter is used in middle stage of system. Input of inverter should not be less than total watt-hour of devices (equipments). Also inverter rated voltage should be equal to use battery. In stand-alone systems inverter should be big enough to tolerate total amount of power used during a special time. Also; size of inverter must be 25%-30% more than total watt-hour of equipments.

$$\text{inverter rated} = (\text{PV capacity} + \text{wind turbine capacity}) \times 1.3 \qquad (7)$$

E. Reliability

Some of the clear factors of reliability are loss of expected load (*LOLE*), loss of Energy (*LOEE*), amount of not-generated energy (*EENS*), probable loss of energy generation (*LPSP*) and equivalent loss factor (*ELF*). *ELF* is one of the main factors which is equal to ratio of effective hours of power-cut to total hour, which is considered in rural area and stand-alone systems, *ELF*<0.01.

$$ELF = \frac{1}{H} \sum_{h}^{H} = 1 \frac{Q(h)}{D(h)} \qquad (8)$$

where H is number of time steps. In this paper reliability factors is calculated by disability of equipment like wind turbine, solar cells, buttery and inverter.

III. SIMULATION AND RESULTS

Load used in this research has been tested in IEEE standards which the information has listed in Table 2.

A. Wind/Battery System

This system consists of battery and wind turbine, which sizing of equipment has been showed in Table 3. Total cost and ELF factor is equal to 3.40795 MUS$ and 0.01. Total cost, in this system, is more than hybrid system and certainly factor has been set in max. amount (0.01), which is very extra for *ELF* and causes to pay fine.

B. PV/Battery System

System is made up of PV and battery sizing of equipment has been showed in Table 4, total costs, *ELF* are equal to 1.50584 MUS$ and 0.0021.

C. PV/Wind/Battery System

This system contains, wind, sun and battery sources which sizing of equipments has been discussed in Table 5.

Table 2. Technical information of load

System parameters	values
Efficiency of SB	85%
Efficiency of inverter	90%
Inflation rate	6%
Interest rate	6%
Life span of project	20
Life span of WTG	20
Life span of PV	20
Life span of SB	10
Life span of inverter	15
PV array price	7000 US$/unit
WTG price	19400 US$/unit
SB price	800 US$/unit
Inverter price	800 US$/unit
Replacement price of WTG	15000 US$/unit
Replacement price of PV array	6000 US$/unit
Replacement price of SB	700 US$/unit
Replacement price of inverter	750 US$/unit
OM costs of WTG	75 US$/unit-yr
OM costs of PV array	20 US$/unit-yr
OM costs of SB	10 US$/unit-yr
OM costs of inverter	8 US$/unit-yr
Cut-in wind speed	3 m/s
Rated wind speed	13 m/s
Cut-out wind speed	25 m/s
Rated WTG power	7.5 kW
Period under observation	8760 hours
Minimum storage level of battery	3 kWh
Maximum total SB capacity	40 kWh
Rated battery capacity	8 kWh

Table 3. Total cost and *ELF* factor for wind/battery system

$N_{w\theta}$	N_{pv}	N_{bat}	$P_{in(\text{Kw})}$	θ_{pv}
173	-	200	47	-

Table 4. Total cost and *ELF* factor for PV/battery system

$N_{w\theta}$	N_{pv}	N_{bat}	$P_{in(\text{Kw})}$	θ_{pv}
-	185	37	45.30	58.82

Table 5. Sizing of equipments for PV/wind/battery system

$N_{w\theta}$	N_{pv}	N_{bat}	$P_{in(\text{Kw})}$	θ_{pv}
13	114	68	47.5	37.33

On early hours batteries are empty (in minimum storage mode). Because of this lots of loads are lost and also ELF factor goes up. But amount of *ELF* during year (0.002) is less than *ELF* limitation during year. So, there will be no need to pay fine. Total cost of this system is 1.29 MUS$. In this system, to choose suitable parameters for MPPT driver control, hybrid system plan of solar and wind energy has been used (PWM converter plan with PMDC motor driver).

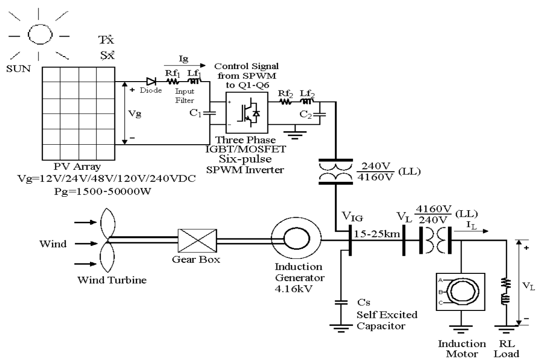

Figure 7. Hybrid system plan of sun and wind

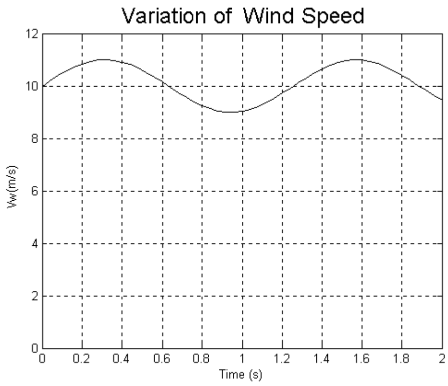

Figure 8. Variation of wind speed

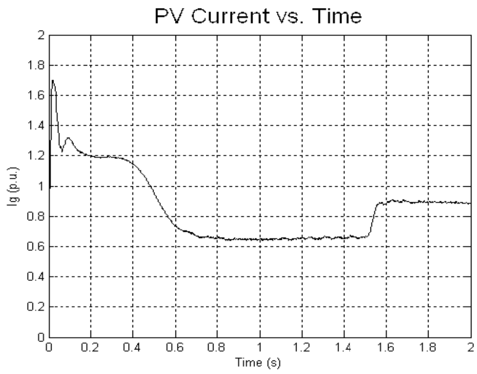

Figure 9. PV current with PL

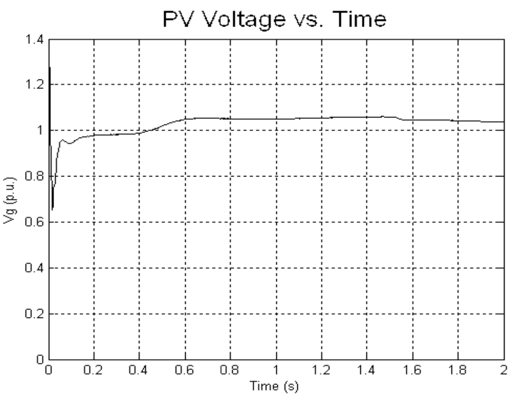

Figure 10. PV voltage with PL

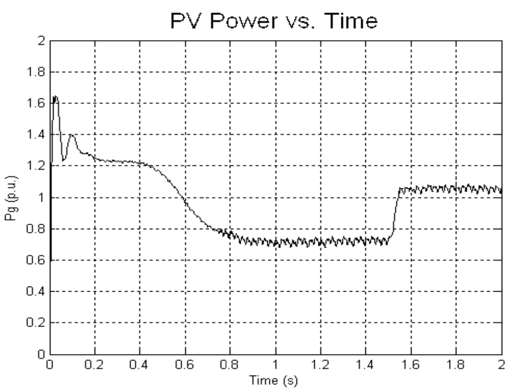

Figure 11. PV power with PL

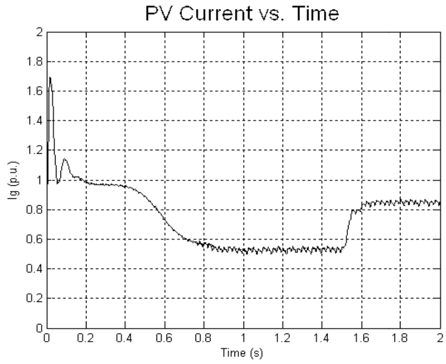

Figure 12. PV current without PL

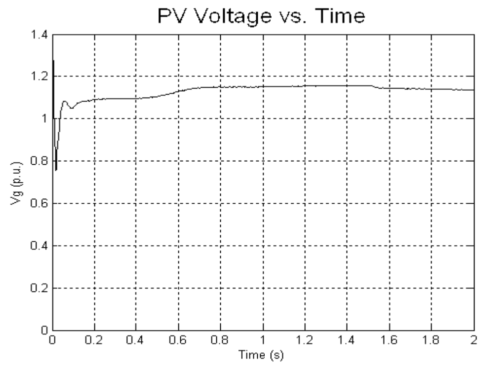

Figure 13. PV voltage without PL

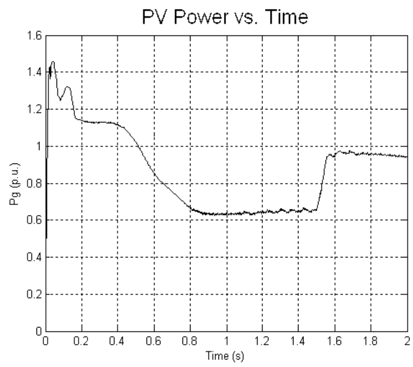

Figure 14. PV power without PL

In wind energy converter new technique and compensator plan suggested in this paper, is Universal DC-Link compensation (UDCC).

- Under Leaner or Nonlinear Load: Between times: 0.1-0.03 sec 50% of leaner load set (100 kVA) and between (0.4-0.6 sec) 60% of nonlinear load are set (120 kVA).

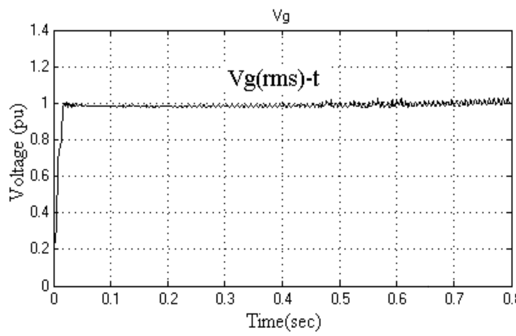

Figure 15. Under electrical load with UDCC voltage

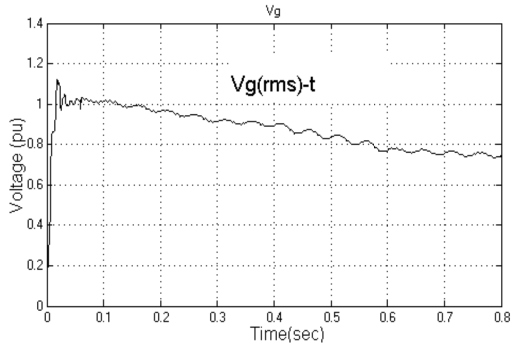

Figure 16. Under electrical load without UDCC voltage

- Under Motor Load: Between 0.2-0.4 sec, 20% of inductive motor load (20 kVA) is set.

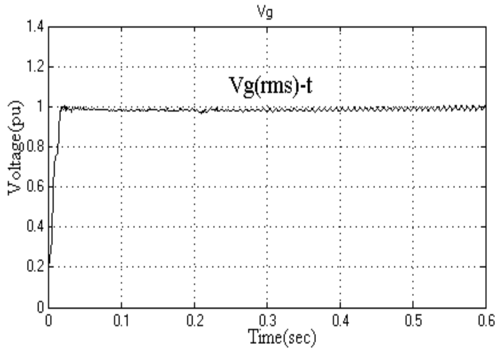

Figure 17. Under motor load with UDCC voltage

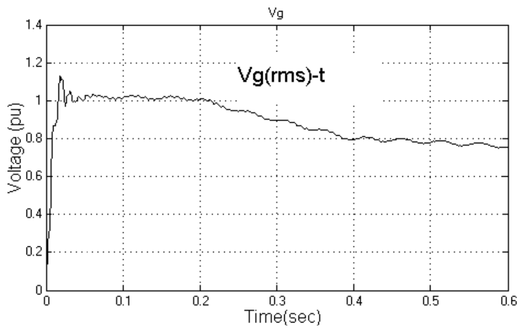

Figure 18. Under motor load without UDCC voltage

- Under Wind Current: In times between 0.3 0.6 sec, wind drops from 10 m/s to 6 m/s.

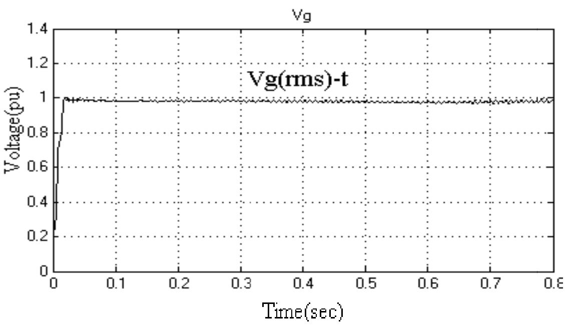

Figure 19. Under wind current with UDCC voltage

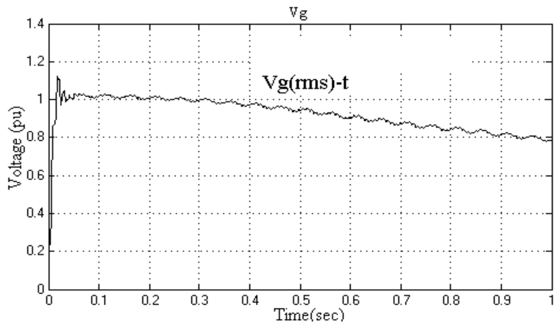

Figure 20. Under wind current without UDCC voltage

- Under Transient Short Circuit Fault (Ground): All of loads are grounded between 0.2-0.4 sec. This plan is very effective in voltage stability for all of electrical loads and stiff wind and 3-phase short circuit fault.

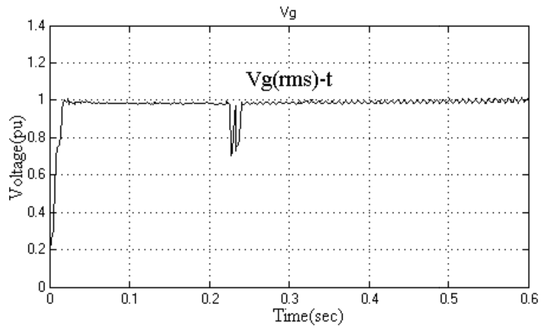

Figure 21. Under short circuit fault with UDCC voltage

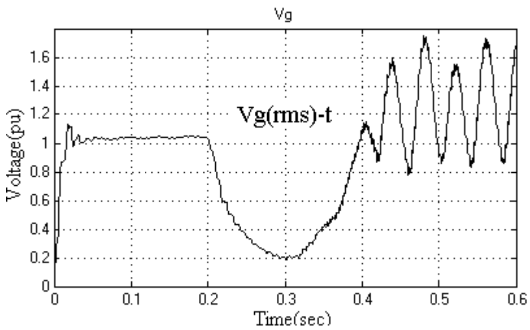

Figure 22. Under short circuit fault without UDCC voltage

IV. CONCLUSIONS

In this paper hybrid system has been designed for some parts of Iran, which can be as a prototype for some parts of world. Also each of sources are by one been analyzed and favorite formation of than has been obtained and also the best configuration has been analyzed and selected. It is recommended to use wind hybrid and solar system. In this condition, reliability at system goes up and according to research done about the region; there are 300 days during year, which there is enough sunlight. This system is more economical than exclusively-wind system.

REFERENCES

[1] F. Fattahi, “Combined Systems of Distributed Generation: Estimation of Characteristics and Parameters of Compatibility their Parallel Work with Power System”, Ph.D. Thesis, Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan, 2010.

[2] S. Heier, "Grid Integration of Wind Energy Conversion Systems", John Wiley & Sons, 1998.
[3] Eltra, "Technical Regulation for the Properties and the Regulation of Wind Turbines", Tech. Rep., Eltransmission, Fredericia, Denmark, December 2004.
[4] "Grid Code, High and Extra High Voltage", Tech. Rep., E.ON Netz GmbH, Bayreuth, Germany, Aug. 2003.
[5] "The Grid Code", Tech. Rep., National Grid Electricity Transmission Plc, London, UK, May 2006.
[6] E. Muljadi, Y. Wan, C.P. Butterfield, B.A. Parsons, "A Study of a Wind Farm Power System", Tech. Rep., NREL/CP-500-30814, National Grid Electricity Transmission Plc, London, UK, January 2002.
[7] J.G. Slootweg, W.L. Kling, "Modelling Wind Turbines for Power System Dynamics Simulations: An Overview", Wind Eng., Vol. 28, No. 1, pp. 7-26, 2004.
[8] V. Akhmatov, "Analysis of Dynamic Behaviour of Electric Power Systems with Large Amount of Wind Power", Ph.D. Thesis, Electric Power Engineering, Ørsted-DTU, Technical University of Denmark, Lyngby, Denmark, 2003.
[9] J.G. Slootweg, "Wind Power Modelling and Impact on Power System Dynamics", Ph.D. Thesis, Ridderprint Offsetdrukkerij B.V., Ridderkerk, The Netherlands, 2003.
[10] Y.A. Kazachkov, J.W. Feltes, R. Zavadil, "Modeling Wind Farms for Power System Stability Studies", IEEE Power Engineering Society General Meeting, IEEE Cat. No. 03CH37491, Toronto, Canada, pp. 1526-33, 2003.
[11] J.M. Rodriguez, J.L. Fernandez, D. Beato, R. Iturbe, J. Usaola, P. Ledesma, et al, "Incidence on Power System Dynamics of High Penetration of Fixed Speed and Doubly Fed Wind Energy Systems: Study of the Spanish Case", IEEE Trans. on Power Systems, Vol. 17, No. 4, pp. 1089-95, 2002.
[12] A. Moeini, A. Darabi, H. Yassami, M.H. Sadeghi, "Optimal DG Allocation in Distribution Network Using Strength Pareto Multi-Objective Optimization Approach", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 2, Vol. 2, No. 1, pp. 50-54, March 2010.
[13] F. Fattahi, A. Rashtchizadeh, N.R. Rahmanov, A.M. Hashimov, N.M. Tabatabaei, "Analysis of DG Systems with Wind Farms in Iran Azarbaijan", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 5, Vol. 2, No. 4, pp. 49-53, December 2010.

BIOGRAPHIES

Farrokh Fattahi was born in Tabriz, Iran and received his B.Sc. degree in Electrical Engineering. He received his M.Sc. degree from Amir-Kabir University, Tehran, Iran in 1998 where he is currently working toward the Ph.D. in Electrical Engineering in Institute of Physics of Azerbaijan National Academy of Sciences, Baku, Azerbaijan. He got the valuable results about application of laser in electrical and electro-medical engineering by license of Cleveland University of USA. Recently, he is studying on management of DG systems on electric network.

Arif M. Hashimov was born in Shahbuz, Nakchivan, Azerbaijan on September 28, 1949. He is a Professor of Power Engineering (1993); Chief Editor of Scientific Journal of "Power Engineering Problems" from 2000; Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan) from 2002 up to 2009; Academician and the First Vice-President of Azerbaijan National Academy of Sciences from 2007. He is laureate of Azerbaijan State Prize (1978); Honored Scientist of Azerbaijan (2005); Cochairman of International Conferences on "Technical and Physical Problems of Power Engineering". His research areas are theory of non-linear electrical chains with distributed parameters, neutral earthing and ferroresonant processes, alternative energy sources, high voltage physics and techniques, electrical physics. His publications are 250 articles and patent and 5 monographs.

Naser Mahdavi Tabatabaei was born in Tehran, Iran, 1967. He received the B.Sc. and the M.Sc. degrees from University of Tabriz (Tabriz, Iran) and the Ph.D. degree from Iran University of Science and Technology (Tehran, Iran), all in Power Electrical Engineering, in 1989, 1992, and 1997, respectively. Currently, he is a Professor of Power Electrical Engineering at International Ecoenergy Academy, International Science and Education Center and International Organization of IOTPE (www.iotpe.com). He is also an academic member of Power Electrical Engineering at Seraj Higher Education Institute (Tabriz, Iran) and teaches power system analysis, power system operation, and reactive power control. He is the secretary of International Conference of ICTPE, editor-in-chief of International Journal of IJTPE and chairman of International Enterprise of IETPE all supported by IOTPE. His research interests are in the area of power quality, energy management systems, ICT in power engineering and virtual e-learning educational systems. He is a member of the Iranian Assoc. of Electrical and Electronic Engineers (IAEEE).

Sabina Guliyeva was born in Baku, Azerbaijan in 1972. In 1995, she has received the M.Sc. degree from Azerbaijan State Oil Academy, Baku, Azerbaijan. Her Ph.D. work was devoted to optimization and forecasting of modes of power systems using models of an artificial intellect. She joined to Azerbaijan Scientific-Research & Design Prospecting Power Engineering Institute in 1996 and now in position of leading engineer.