Double Estimators of Hybrid Power System Parameters for Grid Efficiency Enhancement

MOHAMMAD A OBEIDAT[1] AND SAMER SALAH[1]
[1]Electrical Power and Mechatronics Engineering Department
Tafila Technical University
P.O.Box 179, Zip Code 66110
Tafila
JORDAN
maobaidat76@gmail.com

Abstract: - Highly demand for energy makes the electrical power systems grown rapidly, so thinking of establishing new power sources is required. Alternative Energy sources such as wind farms, photovoltaic PV technology, biomass, hydropower and many deferent new power alternatives are used. The phase angle between the two sources should be controlled for high system efficiency. In this paper the impact of the phase angle of the current inverter is studied. Two estimators for the relations between the phase angle, inverter current, and grid harmonics were developed using matrix approximation method. The response of various types of load under grid connection is measured.

Key-Words: - Estimator, Inverter current, Phase angle, PV source, Wind energy, Matrix approximation.

1 Introduction

A rapid increase in the cost of fossil fuel, which is used in conventional energy sources, make the decision makers employ a new kind of energy sources with lower cost and a friend of the environment. The geometrical region, environmental issues, natural sources and weather conditions should be taken into account before establishing any type of AE source [1].

The use of renewable energy sources adds additional complexity to power systems and makes them more challenging to the operator, the renewable power generation sources can be divided into two categories, the sources which have similar characteristics to conventional power generation facilities in that they are predictable and controllable, such as hydroelectric generation and biomass and the variable and intermittent sources, such as wind and solar [2].

The effect of wind and solar renewable sources on power system stability is different from that of the conventional power sources. Wind and solar are depending on variable conditions such as weather conditions, like wind speed and solar irradiance, site dependence, types of generators used [3].

Today's power system is already complex and poses many challenges for system. Different types of power sources are integrated to run the power systems in a minimum cost and maximum reliability conditions, for this the renewable energy sources are implemented on the modern power systems [4].

The mixed systems of both conventional power sources and renewable power sources became popular and common on different systems sizes. Since the renewable power sources are non-depletable, site dependent, non-polluting and potential sources. Such systems are called hybrid renewable energy power sources HRES. The design of these systems is mainly dependent on the individual system. In order to predict performance, individual components should be modelled first and then their mix can be evaluated to meet the demand reliably [5].

Renewable Generation can only have a considerable impact on systems-wide if there is a considerably high penetration level. In some cases, a regional high penetration level is sufficient for causing a stability problem, in other cases, a considerable impact can only be noticed if the system-wide penetration level is sufficiently high [6].

The hybrid RES has been studied for feasibility analysis, optimum sizing, modelling, control aspects, reliability issues and power quality of the system, where the new power sources add a new component on the power system, wind-powered generators are induction generators [7-10]. The impact of connecting the RES on the electrical power system controlling values such as frequency, voltage, phase angle and active/reactive power has been studied in many papers by generating numerical models to observe the actual performance of isolated power system under deferent levels of RES penetration [11-13].

The modern grids reliability objectives are increased, therefore more challenging due to various factors such as: Aggravated grid congestion, larger transfers over longer distances reducing reliability margins, the grid being operated at its edge in more locations, and massive utilization of distributed resources increases complexity [13].

2 Estimators models and simulations:

2.1 Matrix Approximation Method:

In this paper matrix approximation method is applied, to find out the equation that describes the relation between the grid tied inverter (GTI) current $I_{\mathrm{inv}}(\theta)$ with the phase angle $(\theta)$and the equation that describes the relation between the grid harmonics $H(\theta)$ with the phase angle (θ). This is an optimization technique that can be used to estimate the function using sample data.

$$A = \begin{bmatrix} x1^0 & x1^1 & x1^2 & x1^3 & x1^n \\ x2^0 & x2^1 & x2^2 & x2^3 & x2^n \\ x3^0 & x3^1 & x3^2 & x3^3 & x3^n \end{bmatrix}$$

$$C = \begin{bmatrix} C_0 \\ C_1 \\ C_2 \\ C_3 \\ C_n \end{bmatrix} \qquad D = \begin{bmatrix} f(x1) \\ f(x2) \\ f(x3) \end{bmatrix}$$

Where A is the sample data matrix and D is the output function for different samples.

such that $C^* = (A^T.A)^{-1}.A^T.D$ is the Polynomial coefficients Matrix that gives minimum error between the function and its estimation.

$$est\, f(x) = C_0 + C_1X + C_2x^2 + C_3X^3 + C_4X^4 + \cdots + C_nX^n$$

2.2 Effect of Phase Angle on GTI Current and Grid Harmonics:

In this paper the estimation block diagram of hybrid system is built as shown in Figure 1. It is noticed that when the phase angle increase, the grid current decrease, the grid harmonics increase and the inverter current increase. Figures 1 and 2 show the block diagram for estimation process of Hybrid system and its Simulink implementation.

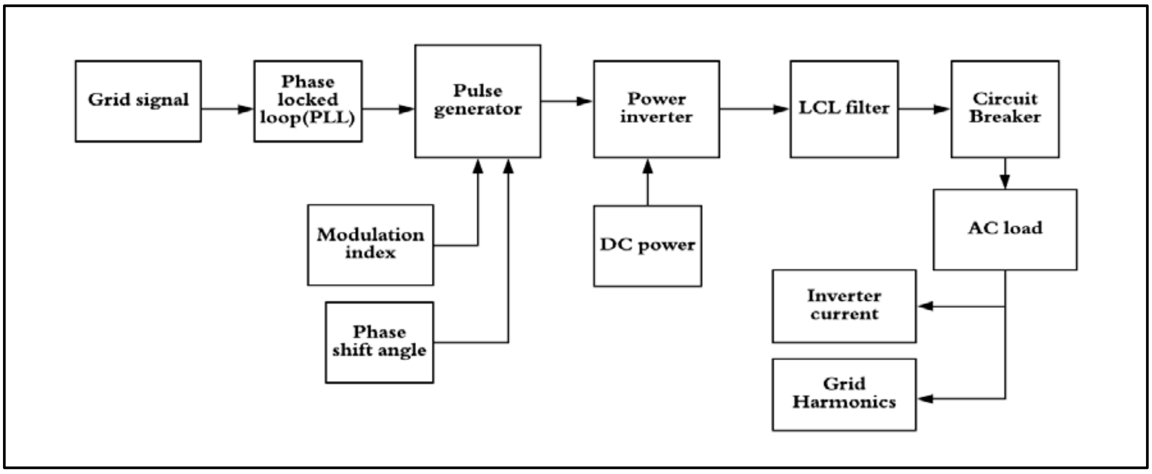

Fig. 1 Block diagram for estimation process of Hybrid system

Fig. 2 Hybrid Electrical Power System Simulink

2.2 Effect of Phase Angle on GTI Current and Grid Harmonics:

We notice that when the phase angle increase, the grid current decrease, the grid harmonics increase and the inverter current increase.

2.3 GTI current Estimation:

$$f_{5th}(x) = 318.35 - 1151.513X + 1543.391x^2 - 947.303X^3 + 283.71X^4 - 33.278X^5$$

$$f_{4th}(x) = 45.625 - 224.48X + 305.344x^2 - 134.943X^3 + 21.643X^4$$

$$f_{3rd}(x) = -71.351 + 92.882X - 10.163x^2 + 1.411X^3$$

$$f_{2nd}(x) = -66.318 + 82.688X - 3.497x^2$$

$$f_{1st}(x) = -58.061 + 71.671X$$

Table 1 Inverter current estimation error.

Estimation	SSE
5th degree	14.06259
4th degree	14.276402
3rd degree	15.31636
2nd degree	15.36606
1st degree	18.71826

2.4 Grid Harmonics Estimation:

$$f_{5th}(x) = -624.167 + 2142.785X - 2869.561x^2 + 1895.091X^3 - 617.386X^4 + 80.041X^5$$

$$f_{4th}(x) = 31.792 - 86.918X + 108.194x^2 - 58.802X^3 + 12.938X^4$$

$$f_{3rd}(x) = -38.133 + 102.792X - 80.406x^2 + 22.706X^3$$

$$f_{2nd}(x) = 42.886 - 61.3X + 26.88x^2$$

$$f_{1st}(x) = -20.574 + 23.374$$

Table 2 Grid harmonics estimation error.

Estimation	SSE
5th degree	28.78846
4th degree	30.0253518
3rd degree	30.3969601
2nd degree	43.27376
1st degree	241.31435

2.5 Various loads behaviour under Grid

Connection:

1. Inductive load: Θ = 1.5 degree.

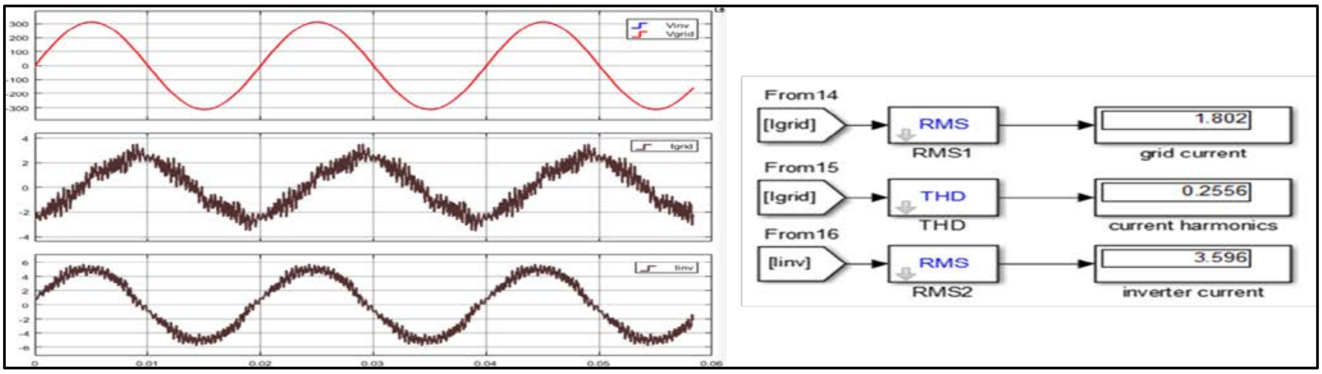

Fig. 4 Inductive Load Response Results.

2. Resistive load: Θ = 1.5 degree.

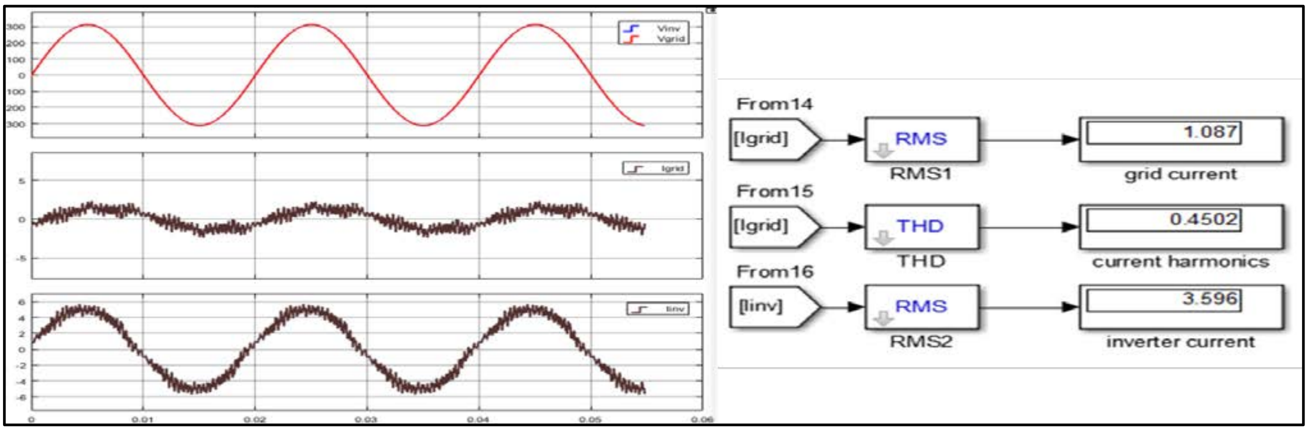

Fig. 5 Resistive Load Response Results.

2. Nonlinear load: Θ = 1.5 degree.

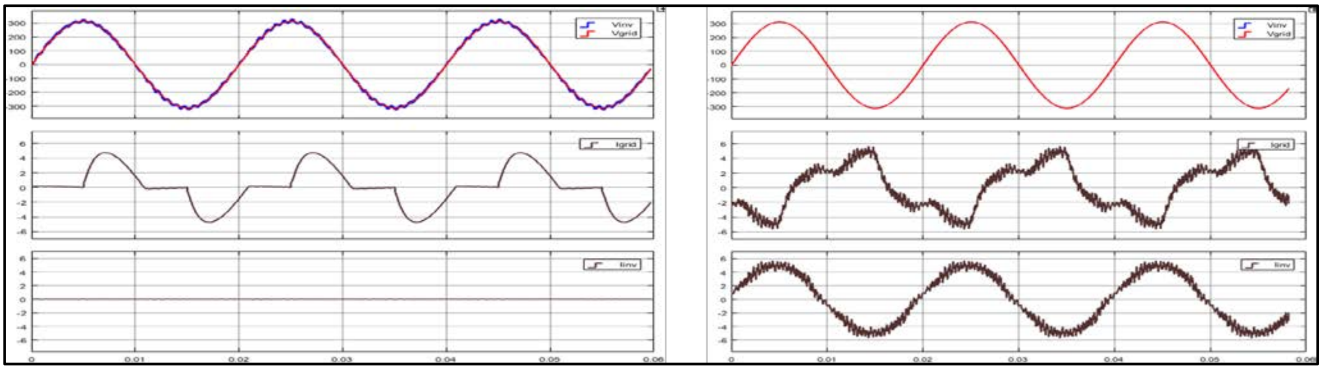

Fig. 6 Nonlinear Load Response Results.

3 Conclusion:

Second degree estimator is used to estimate the relation between inverter current and phase angle. A third-degree estimator is built to estimate the relation between grid harmonics and phase angle. It has been noted that, the inductive load is preferred to be used, in order to reduce the harmonic contents in the grid current compared with the resistive load. For the nonlinear load it will absorb current as usual but the inverter will improve the grid quality.

References

[1] A. Al-Azzam and Amani, ‘The Grid (Opportunity vs. Challenges)’, Jordanian Forum Renew. Energy, 2014.

[2] V. Khare, S. Nema, and P. Baredar, ‘Solar-wind hybrid renewable energy system: A review’, Renew. Sustain. Energy Rev., vol. 58, pp. 23–33, 2016.

[3] V. Vittal and T. G. Heydt, ‘Impact of large scale PV generation’, pp. 1–1, 2014.

[4] ‘Ministry of Energy and Mineral Resources (MEMR) of Jordan’.

[5] ‘The Royal Scientific Society (RSS)’.

[6] ‘National Electrical Power Company’. [Online]. Available: http://www.nepco.com.jo/statistical_info_ar.aspx.

[7] J. Dudiak and M. Kolcun, ‘Integration of renewable energy sources to the power system’, 2014 14th Int. Conf. Environ. Electr. Eng., no. June, pp. 148–151, 2014.

[8] M. K. Deshmukh and S. S. Deshmukh, ‘Modeling of hybrid renewable energy systems’, Renew. Sustain. Energy Rev., vol. 12, no. 1, pp. 235–249, 2008.

[9] P. Kundur, ‘Definition and classification of power system stability. IEEE/CIGR joint task force on stability terms and definitions’, IEEE Trans. Power Syst., 2004.

[10] K. Elkington, The Dynamic Impact of Large Wind Farms on Power System Stability. 2012.

[11] R. Shah, N. Mithulananthan, A. Sode-Yome, and K. Y. Lee, ‘Impact of large-scale PV penetration on power system oscillatory stability’, IEEE PES Gen. Meet. PES 2010, pp. 1–7, 2010.

[12] H. Holttinen, The impact of large scale wind power production on the Nordic electricity system. 2004.

[13] C. Jauch, J. Matevosyan, T. Ackermann, and S. Bolik, ‘International comparison of requirements for connection of wind turbines to power systems’, Wind Energy, vol. 8, no. 3, pp. 295–306, 2005.

[14] P. S. Panel and P. Affairs, ‘Integrating Renewable Electricity on the Grid A Report by the APS Panel on Public Affairs’, Leadership, pp. 1–38, 2010.

[15] A. Omole, ‘Voltage Stability Impact of Grid-Tied Photovoltaic Systems Utilizing Dynamic Reactive Power Control’, p. 168, 2010.

[16] G. Balaban, G. C. Lazaroiu, V. Dumbrava, and C. A. Sima, ‘Analysing Renewable Energy Source Impacts on Power System National Network Code / Romania’, 2017.

[17] P. Sharma, T. S. Bhatti, and K. S. S. Ramakrishna, ‘Study of an isolated wind – diesel hybrid power system with STATCOM by incorporating a new mathematical model of PMIG’, no. February 2011, pp. 351–363, 2012.