Modeling and Simulation of a modern renewable energy to be used in a urban and far Iraqi areas

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Abstract

This research aims to model and simulate the transient and steady state behavior of wind turbine systems. This work could have a broad scope, that being the ease, in aims to lay groundwork which will allow for further investigation and for the development of a more sophisticated micro-turbine model. More specifically it involves modeling a micro turbine and a wind turbine block sets, and time allowing combining these models to form a micro-grid.

Currently models of a wind turbine and a gas turbine have been developed. These are connected to a load and the mains power supply. More accurate results will be achieved for the wind and micro-turbine. Also, it is hoped that the sources will together power a single load.

1. Introduction

As energy generation and distribution sources work an increasing interest in renewable and alternative energy supplies. In addition customers are seeking higher quality and cleaner electricity. Besides electrical engineers working for new energy generation methods. One solution which is currently attracting attention are micro-grid systems [1].

Micro-grid systems are comprised of several alternative energy sources. They can include solar cells, wind turbines, micro-turbines(natural gas), fuel cells and storage batteries. They are connected to the main power grid and placed on the site that is to use the system. It is connected to the low voltage distribution network through power electronics. Fig.(1) shows how a micro-grid could look relative to the main power supply.

There are several reasons why micro-grids are so interesting. First, because they are involved alternative energy sources, and most alternative offer far higher efficiency and less environmental issues than standard power generation. Furthermore, since they are to be on the site which they are to supply, losses due to transmitting electricity is proportionally eliminated, which makes micro-grids even more efficient and cleaner than their standard counterpart. Finally, it is possible to make a micro-grid to provide the needs of the area that will be servicing. That is, it can be basic and provide energy for lighting only as required by some remote villages. Alternatively, it can provide high quality, uninterrupted electricity as may be needed by companies who use highly sensitive [2,3].

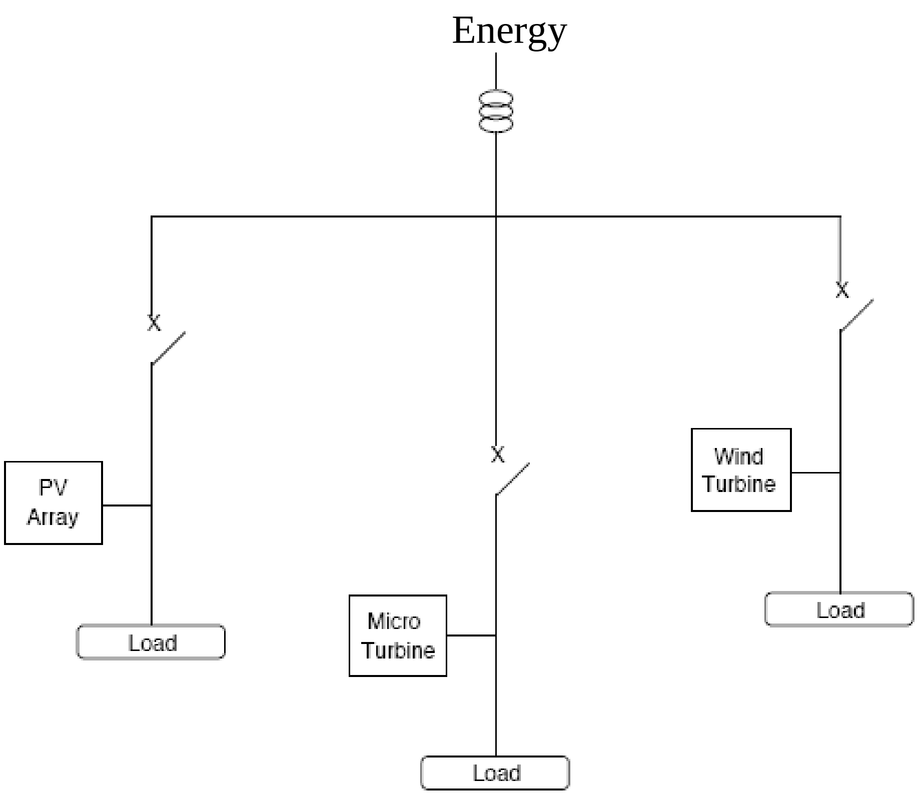

Fig.(1) A micro-grid system

When several sources are connected to form a micro-grid the systems behavior is unpredictable. This being the case, modeling the system and investigating it in order to evolve an appropriate control system is the heart of micro-grid research. Some issues they are encountering include dealing with unbalanced loads and harmonics associated with the system. This work is concerned with the modeling of the system for the investigation of the transient and steady state response.

The building of micro-grid systems started in 2003 in some places in the world. They hope it will service five commercial and industrial facilities, and up to 12 residences. They are currently in the engineering phase. On site they have a micro-system setup, the system has a photovoltaic array, several wind turbines, several micro-turbines, a fuel cell and batteries. They are currently in the process of researching the micro-grid system and modeling its features. This research aims to lay the ground work for the development of such a model. Also the goal of this work is to build a block set of power sources, their power electronics as well as a load and mains model in MATLAB/Simulink [4]. Fig.(2) shows a picture of the suggested system. [2]

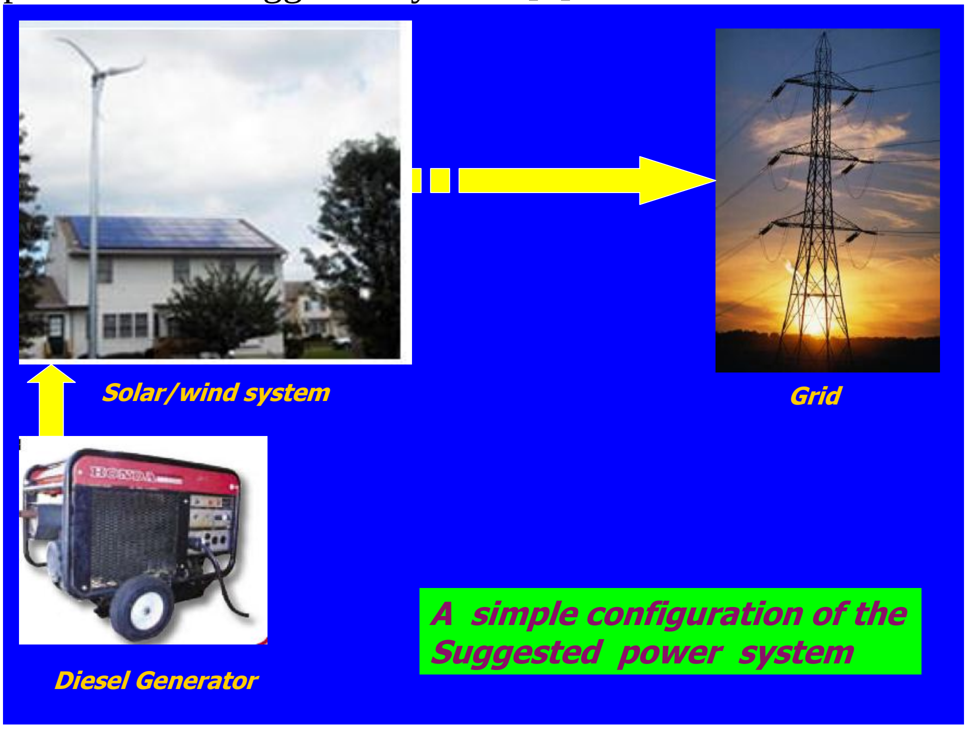

Fig.(2) The complete system

2. Theory and Implementation of Modeling a Micro-grid

The concept of micro-grid is a very new one. Consequently, it is difficult to find any information which is useful for the research. The best method for understanding what is complicated about a micro-grid, that is why it produced such unexpected behavior, is to modeling a component. It became evident at this work that each source would be modeled individually and then combined together to form a micro-grid, rather than modeling it in a monolithic fashion. It is important to note that to the main grid a micro-grid appears as a single power source. [2]

The research plan was to model a photovoltaic array, a wind turbine and a micro-turbine. Particularly modeling the power source and the power electronics associated with the system was important, this was done using Simulink. Each model was to be completed independently, ad then time allowing connected in a micro-grid configuration. The research goal was a working model of a micro-grid system. A block diagram of a micro-grid system configuration is shown in Fig.(3). The top layer will simply be the power source, the inverter and the mains and load blocks [5].

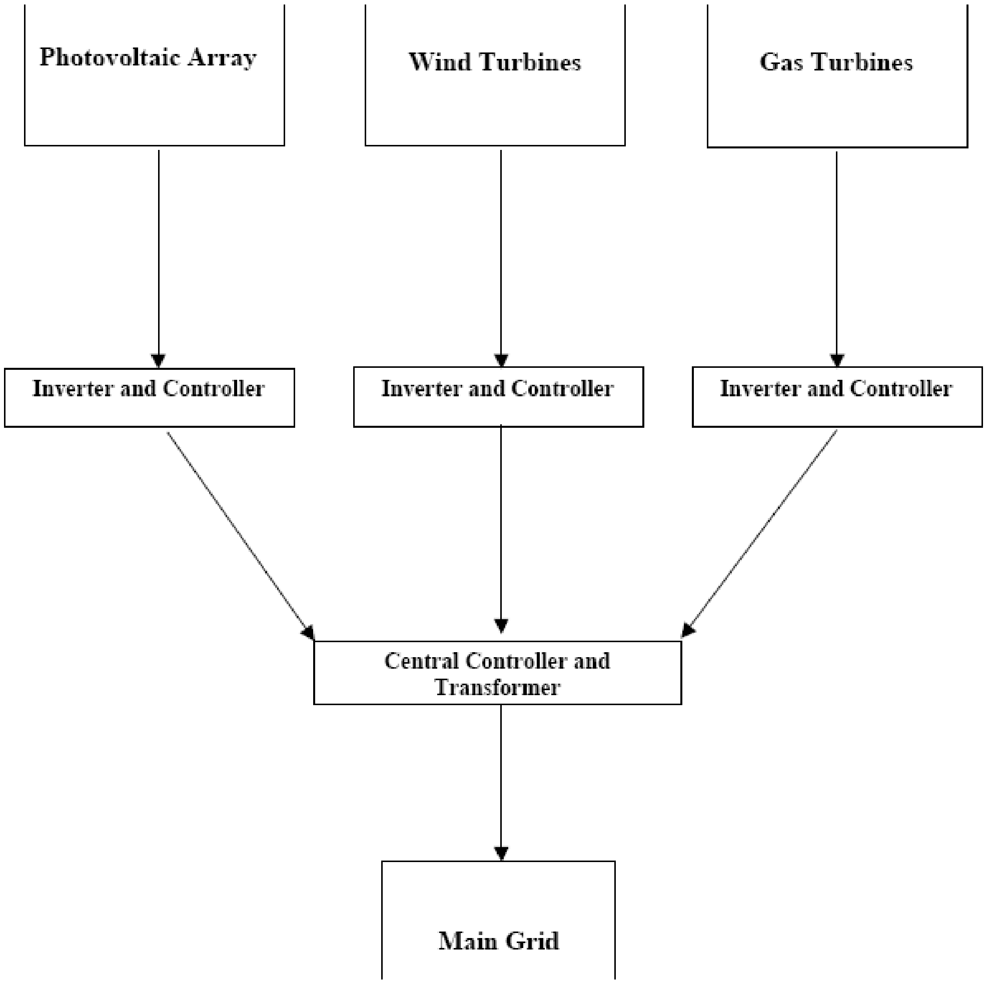

Fig.(3) Block diagram of a Micro-grid System

2.1 Photovoltaic Array Model

A possible model of a photovoltaic array and inverter was researched. After verifying the theory its features were modeled in Simulink. This proved more time consuming and complicated than intended. Like the theory, the model worked with both load and no load conditions.

Fig.(4) shows the model of the PV array system. The blocks of the most interest are shown on the top layer as seen in the diagram. An important decision with the array was to decide to model it is either with current or voltage as the output, current was chosen because that is what the model in question had done and because it seemed the most rational in light of the model in question had done and because it seemed the most topologies were considered. This has proved successful, however once the load mains were included in the model the system behavior became somewhat undesirable. To address this problem the parameters within the mains and load were varied and the model was checked for errors [4,5].

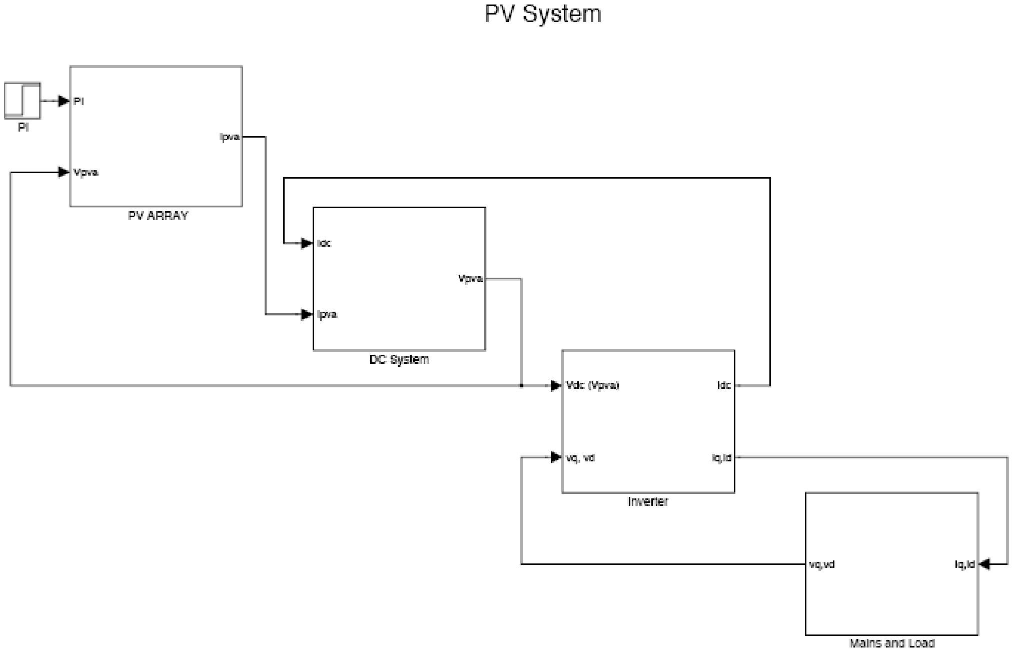

Fig.(4) The PV array system

2.1.1 The PV array

The equation used to describe the PV array model is given by:

$$I_{PVA}= I_{SCA}\, P_I\, 0.01 + K_{IA}(T_C\text{-}28) - I_{OA}(e^{\alpha V_{PVA}} - 1) \quad \ldots\ldots\ldots(1)$$

Where,

I_{PVA} = DC current out of array.

I_{SCA} = short circuit current at 28 C.

P_I = cell illumination in mw/cm^2.

K_{IA}= short circuit temperature coefficient at I_{SCA}.

T_C = short circuit temperature coefficient.

I_{OA} = operating current of array at T_r.

α = constant dependent on particular array.

V_{PVA} = voltage produced by array.

As the derivation of this equation is not significant here, the modeling of this block was relatively straight forward. This block takes an input of w/m^2 and V_{PVA} , it outputs I_{PVA} , the DC current out of the PV array[6].

2.1.2 The DC System

The DC system block is the capacitor in parallel with the array, as seen in Fig.(5). It serves to smooth the DC harmonics and also to limit the rate of change of voltage passed to the inverter system. It takes I_{DC}, the inverter operating current as an input, along with I_{PVA} in order to supply the

DC voltage V_{PVA} to the inverter. Consequently, it contains a control closed loop with an integral control action defined by:

$$e_d - v_d = ri_d + X\, i_q \quad \text{……………..(2)}$$

where r and X respectively represent the resistance and reactance of the inverter system. The final part of the inverter system calculates the I_{DC}, the inverter DC operating voltage. This is passed to the DC system as described before and used to calculate V_{PVA}. The equation which describes this model is defined by:

$$I_{DC} = 1/V_{PVA}(e_q i_q + e_d i_d) \quad \text{……………(3)} \qquad [6]$$

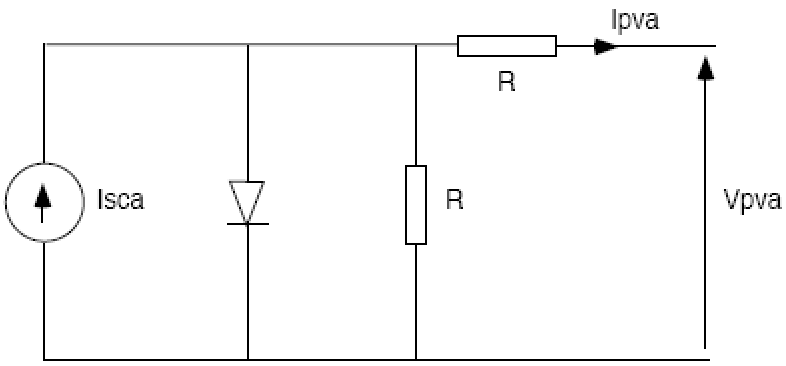

Fig.(5) Circuit diagram of photovoltaic system

2.3 Wind Turbine and Micro-Turbine Modeling

It was expected that all the sources would have similar features. However, due to the nature of turbines, this did not prove to be the ease. It did not provide a big picture idea as to what might be reasonably be expected as an outcomes for the power sources individually. Furthermore, the research process for the PV array was refined and mimicked for the other two sources, hence reducing time taken to research and model each power source. A wind turbine with battery storage connected to a PV array was found. Unfortunately, the PV array is not discussed in this paper**,** however ignoring the battery storage system the wind turbine and its inverter system components were modeled in Simulink. [6]

Fig.(6) shows the model of the wind turbine developed. As with the PV array the system is modeled in blocks, and layers.

The blocks of specific interest are shown in the top layer model. They are the wind generator, the inverter and the mains and load modules. This same model is used for the micro-turbine [7,8].

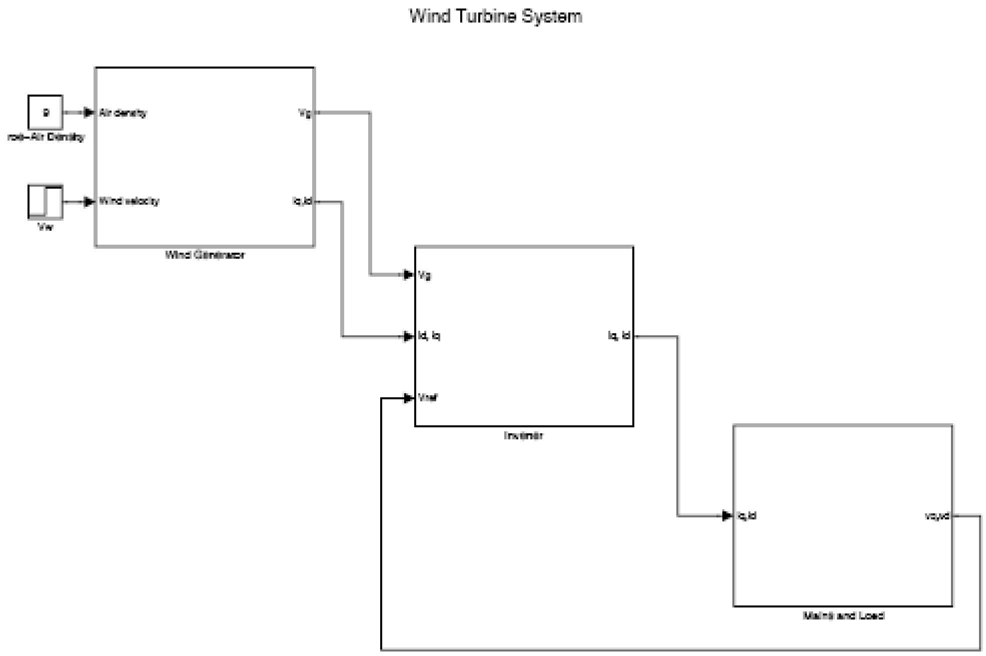

Fig.(6) Wind Turbine System

2.3.1 Wind and Micro-Turbine

The main components of the micro-grid model of the micro-grid model are the wind turbine and the micro-turbine, which is driven by natural gas. Recently, micro-turbines have attracted much attention. This has been primarily due to their ability, through recent technology to produce highly efficient, low emission reliable energy [1]. A significant advantage offered by micro-turbines is their ability to be adapted into an combined heat and power system. In such system the exhaust heat from the micro-turbine is reused, often this is in the air conditioner to reduce running costs and improve system efficiency [9,10].

The important aspects of a wind turbine for the purposes of modeling is the equation which describes it mechanical power output, P_m. The equation following was used to model the wind turbine: [7]

$$P_t=1/2C_p(\lambda)\rho V_w^3 \quad ……………..[4]$$

where,

ρ= air density in kg/m^3

A= frontal area of wind turbine in m^2

V_w=speed of wind ms^{-1}

And $C_p(\lambda)$ is defined by the power coefficient C_p versus tip-speed ratio λ. Since $P_t=T_{twm}$, where T_t=torque and ω_m=angular velocity of the turbine motor we have:

$$T_t=1/2\ \rho\ A_T\ C_T(\lambda) V_w^3 \quad ……………..[5]$$

where,

r= radius of rotor in m

$$C_T(\lambda) = C_p(\lambda)/\lambda \quad ....[6]$$

The wind turbine model and indeed the micro-turbine model interface to the mains quite differently. This is due to the nature of the turbine. A turbine will drive a generator which produces an AC voltage (and current), this is then converted to DC, conditional, inverted to the load and mains power supply through a transformer. A possible configuration with a wind turbine as the power source is shown in Fig.(7). It can be seen that an extra step is required in conditioning the source output to ensure it is mains quality [11,12].

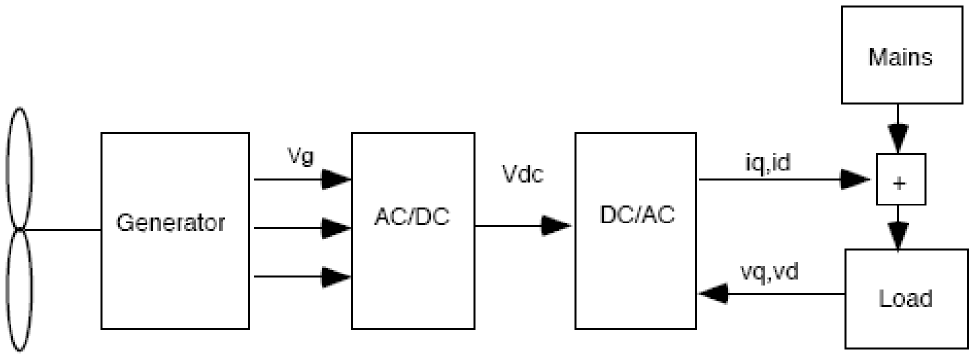

Fig.(7) Block diagram of wind turbine system

2.3.2 The Inverter

The inverter has two stages, the first stage is the AC/DC rectifier and following the DC/AC inverter and transformer. The rectifier takes V_s to DC voltage and current.

The second part is the DC/AC inverter and transformer block. The purpose of this model is to statically invert the voltage V_{DC}. Fig.(7) shows a micro-grid system.

3. Micro-grid Modeling Results

The goal of this work was to research and develop suitable models for several alternative power sources. The models are to be used for further investigation into micro-grid system behavior and for the development of more accurate model.

3.1 Photovoltaic Array System Results

The individual components were attempted separately, as seen in Fig.(4). The starting point was modeling of the PV array. It was hard to accurately test the individual components before the system was completed. However, when all components were completed it worked as expected. The result is a system which very closely resembles the desired system response [4].

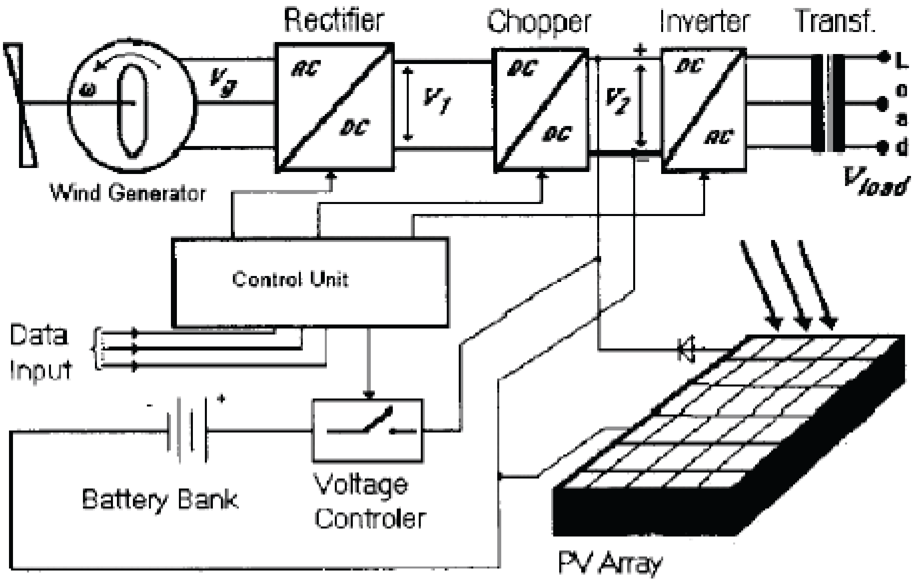

Fig.(8) A Micro-grid System

To illustrate the success of the photovoltaic model in response to a changing input four different simulations that were carried out are presented here. The first set of results are for a constant insulation of 100 W/cm^3, these results illustrate the steady state for the system. Fig.(9) shows the systems behavior to the constant input in insulation. It can be seen that I_{PVA} is constant, V_{PVA} reactive and real power supplied respectively. Fig.(11) shows the system response to a decrease in insulation, from 100 to 10. As would be expected I_{PVA} drops as the insulation does and to allow this to happen instantly V_{PVA} has some recover time before settling. Q_{ac} and P_{ac} react at 0.6s as would be hoped and for a lower insulation they are able to track the power reference more accurately. [8]

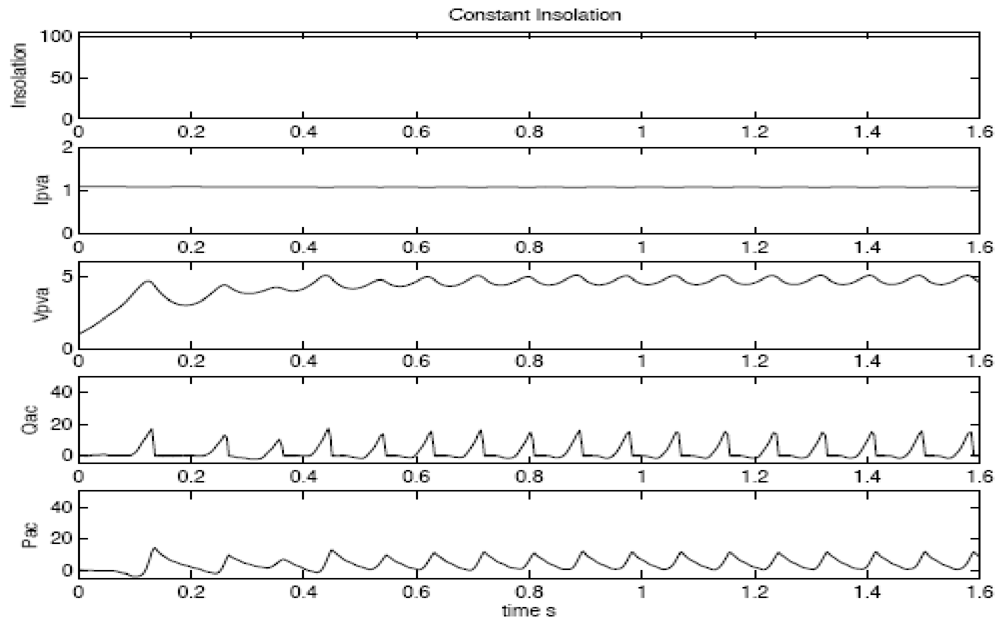

Fig.(9) System response for constant input

Fig.(10) illustrates the system response for an increase in insulation.

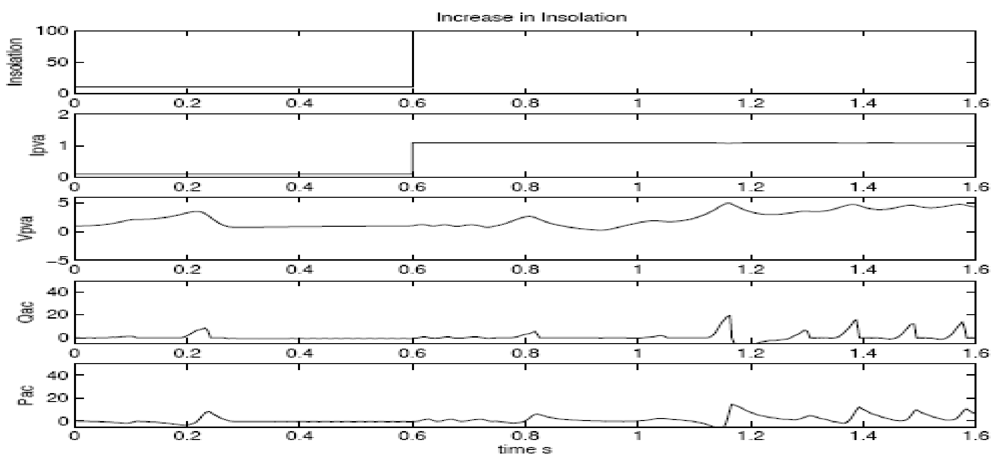

Fig.(10) System response to an increasing input

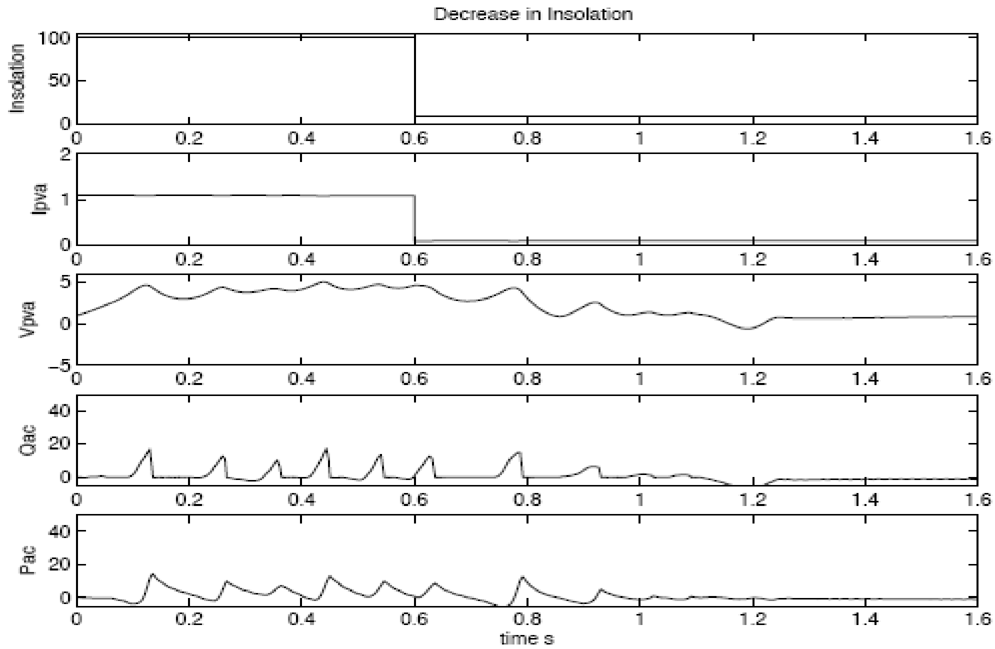

Fig.(11) Wind and Micro-Turbine System Response

3.2 Wind and Micro-Turbine System Results

Fig.(11) shows the DC response to an increase in wind speed. The major control for these systems as discussed before is in the rectifier. As can be seen the voltage, V_{dc} is constant in spite a change in input. This is also shown in Fig.(12) for decrease in wind speed. It is anticipated that the rest of the system will be developed further and demonstrated as the results shown indicate a major and important part of the model works as predicted.

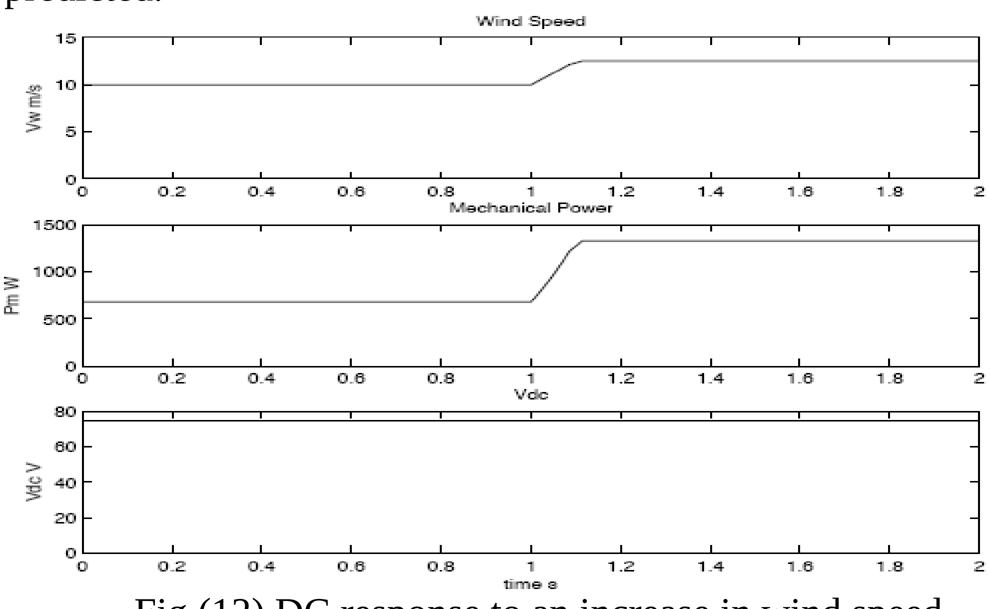

Fig.(12) DC response to an increase in wind speed

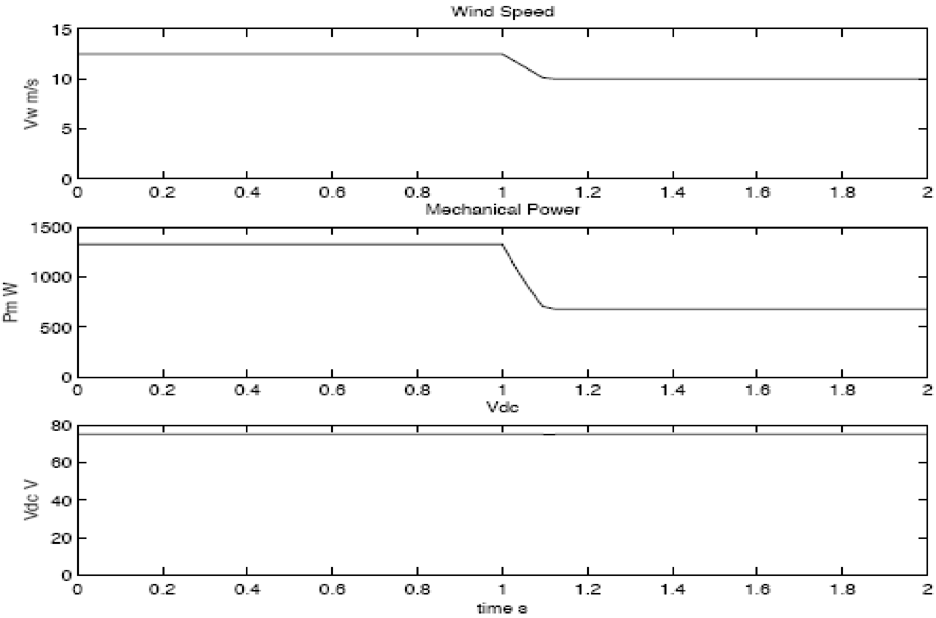

Fig.(13) DC response to a decrease in wind speed

3.2.2 The Micro-turbine

As the wind and micro-turbine systems are so alike the results for the micro-turbine are also very similar to those for the wind turbine. As can be seen in Fig.(14) the voltage out of the rectifier, V_{dc} is constant for a charging input in power (and consequently torque). Again, it is anticipated the system with the mains and load will be developed further and demonstrated.

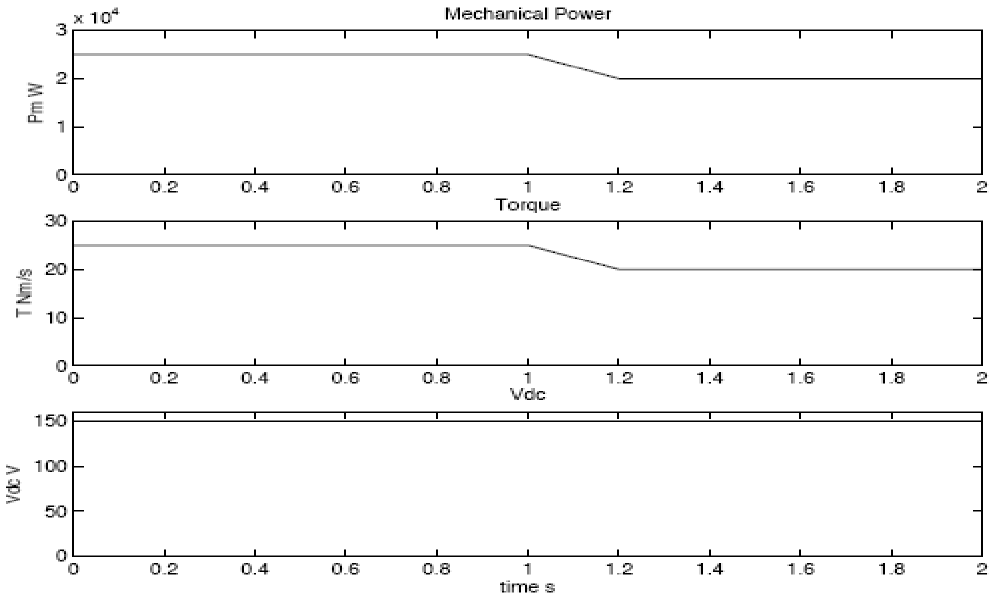

Fig.(14) DC response to an increase in power

3.3 Summary of Results

It has been shown that the models developed describe the real system behavior well. Specifically, the PV array model has been shown to be accurate and respond well to a step input. That is, the systems behavior matches the desired results and reflects real system well.

For the wind and micro-turbine systems the current results are successful as discussed. It is hoped they will be developed further. The methods for doing this were discussed earlier, and are those same principals used when modeling and developing the PV array model.

4. Conclusion of Micro-grid Modeling

This work is discussed in terms of what it aims and how it could contribute to the power industry's needs. It also explores, how the work could be extended or improved and how this might be done. This includes what can be done in the future to understand micro-grid behavior, with the aim of micro-grids use and commercial development.

4.1 Research Conclusions

By making use of the small and varied sources which comprise it, micro-grids may be able to make a significant contribution to the power generation and distribution. For instance, if the sun is out the PV array may provide power, if it's windy the wind turbine, if it is neither or if more power is needed, the micro-turbine or mains supply can be used. The inclusion of batteries in a micro-grid system would also allow excess power produced to be stored, or alternatively the excess power could be put into the main grid. In this way it is expected that micro-grids could reduce pollution and deliver reliable energy in a variety of situations. Micro-grid behavior is on the whole not well understood. For this reason the research aimed to develop models suitable for analysis and investigation.

The work aim was to model the transient and steady state behavior of micro-grid's individual power sources, and time allowing a micro-grid system. A final aim was to lay groundwork which would allow analysis for the further development of a more sophisticated model. More specifically, it involved modeling a photovoltaic cell, a micro-turbine and a wind turbine. All models developed will allow for investigation that will provide an understanding of micro-grids to facilitate the evolution of a more sophisticated model.

The work was carried out by way of extensive research, model design, modeling, testing and development. The sources will be connected together to power a single load.

4.2 Micro-grid Modeling and the Future

The aims of this work were prescribed in terms of how the model developed will be used. It is important to know more about how the sources interact with each other that is do they enhance or interfere with each other.

Another aspect that could be developed further are the individual sources within the micro-grid. This means as science and engineering develop more efficient technology the system should be updated also. In the area of PV arrays and micro turbines technology is constantly changing and improving.

As there other power sources being considered for use in micro-grids the research and modeling of them will at some point be necessary. The sources being considered include fuel cells and batteries which provide electrical storage.

The final important aspect is to obtain some actual micro-grid data(rather than data from individual power sources). It was difficult to find any actual data from implemented micro-grids. This is likely due to micro-grids being a very recent idea and therefore no data being available.

5. REFERENCES

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الخلاصة:

ظهرت الحاجة فى الاونة الاخيرة الى تصميم منظومات كهربائية متكاملة باستخدام مصادر متنوعة من مصادر الطاقة البديلة. هذه المنظومات تتكون من الواح الطاقة الشمسية ومحركات الهواء اضافة الى منظومات الديزل لتوليد الطاقة الكهربائية.

وفى هذا البحث تم تصميم ومحاكاة منظومة متكاملة واختبارها باشارات مختلفة وتم التصميم والمحاكاة باستخدام برنامج ماتلاب كما تم فى هذا البحث دراسة ومحاكاة كم منظومة على انفراد ودراسة خصائصها.