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MODELLING AND CONTROL FOR SMART GRID INTEGRATION OF SOLAR/WIND ENERGY CONVERSION SYSTEM

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Abstract: Performance optimization, system reliability and operational efficiency are key characteristics of smart grid systems. In this paper a novel model of smart grid-connected PV/WT hybrid system is developed. It comprises photovoltaic array, wind turbine, asynchronous (induction) generator, controller and converters. The model is implemented using MATLAB/SIMULINK software package. Perturb and observe (P&O) algorithm is used for maximizing the generated power based on maximum power point tracker (MPPT) implementation. The dynamic behavior of the proposed model is examined under different operating conditions. Solar irradiance, temperature and wind speed data is gathered from a grid connected, 28.8kW solar power system located in central Manchester. Real-time measured parameters are used as inputs for the developed system. The proposed model and its control strategy offer a proper tool for smart grid performance optimization.

I. INTRODUCTION

The limitations of global resources of fossil and nuclear fuel, has necessitated an urgent search for alternative sources of energy. Therefore, a new way has to be found to balance the supply and demand without resorting to coal and gas fuelled generators. Smart grid is a system that would enable the integration of renewable energy sources and shift from reliance on fossil fuels, while maintaining the balance between supply and demand. The key characteristics of smart grid include [1]:

- Grid optimization: system reliability and operational efficiency.
- Distributed generation: not only traditional large power stations, but also individual PV panels, micro-wind, etc.
- Advanced metering infrastructure (AMI): smart meters.
- Grid-scale storage.
- Demand response.
- Plug-in hybrid electric vehicles (PHEVs) and vehicle to grid (V2G).

This paper focuses mainly on the smart grid integration of PV/WT hybrid system (grid optimization and distribution generation).In this study, a detailed dynamic model, control and simulation of a smart grid-connected PV/WT hybrid power generation system is proposed. Modeling and simulation are implemented using MATLAB/SIMULINK and Sims Power Systems software packages to verify the effectiveness of the proposed system. In this paper panel contribution, the modeling of wind turbines in power systems dynamics simulations is discussed. First the three most important actual wind turbine concepts are described. Then, various classes of wind turbine models are introduced and it will be discussed which model type can be integrated in power system dynamics simulation software. To conclude, it will be argued that it is possible to model various kinds of variable speed wind turbines with only one model in power system dynamics simulations.

In this investigation, wind turbine generators, photovoltaic panels, and storage batteries are used to build a grid linked generation system which is optimal in terms of multiple criteria including cost, reliability, and emissions. Multidisciplinary design facilitates the decision maker to make more rational evaluations. A set of trade off solutions can be obtained using the multidisciplinary approach, which offers many design alternatives to the decision maker. A customized particle swarm optimization algorithm is developed to derive these non-dominated solutions.

A grid linked hybrid power system is designed based on the proposed approach. In the present study therefore, a wind power generation system (WPGS), PV generation system (PVGS), and BESS hybrid power generation system (Fig. 1) were considered. Then, a fuzzy logic and wavelet transform based smoothing control strategy was proposed for instantaneous WP and PV power generations smoothing by on-line regulation of battery output power. This paper is organized as follows. Section II presents the modeling of each power source. Simulation results are discussed in Section III. Section IV is the conclusions.

II. SYSTEM DESCRIPTION AND MODELING

Smart grid is a system consists of three layers: the physical power layer, the control layer and the application layer. And according to, Katherine Hamilton [1], smart grid has to be dynamic and have constant two-way communication, as shown in Fig.1. So, for example, with PV panels on the roofs, intelligent building system will generates, store and use their own energy. Hence, as active buildings they become part of the smart grid. This could save energy and increase reliability and transparency.

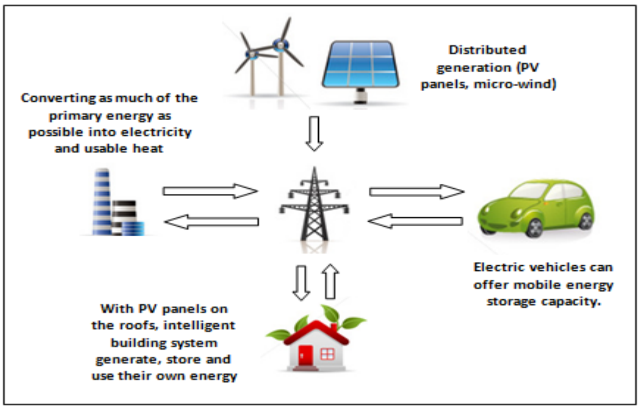


Fig. 1. General layout of the smart grid

In this section, the dynamic simulation model is described for photovoltaic/wind turbine hybrid generation system. The developed system consists of a photovoltaic array, dc/dc converter with an isolated transformer, designed for achieving the MPP with a current reference control (Iref) produced by P&O algorithm, wind turbine, asynchronous induction generator, and ac/dc thyristor controlled double-bridge rectifier.

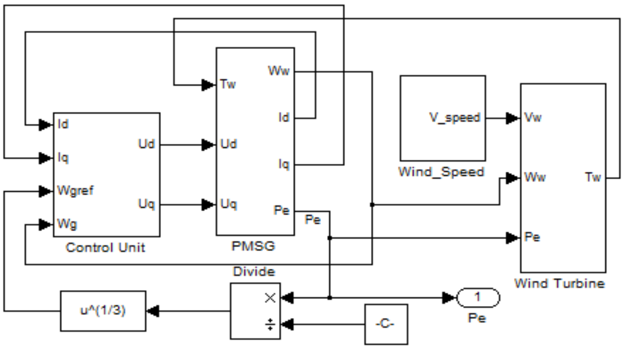


Fig. 2 Model of WPGS using MATLAB/SIMULINK

A. Modelling and Design of a Photovoltaic Module

The general mathematical model for the solar cell has been studied over the past three decades [12]. The circuit of the solar cell model, which consists of a photocurrent, diode, parallel resistor (leakage current) and a series resistor; is shown in Fig. 3. According to both the PV cell circuit shown in Fig. 3 and Kirchhoff's circuit laws, the photovoltaic current can be presented as follows [13]:

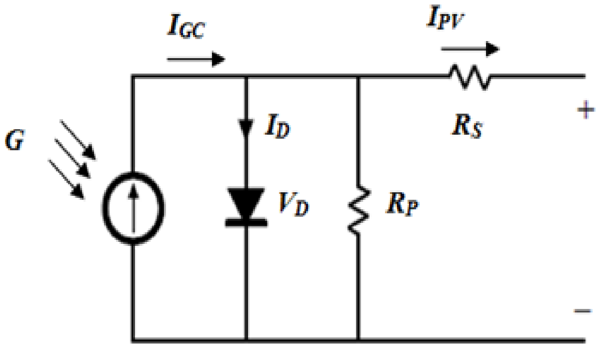


Fig. 3. Single diode PV cell equivalent circuit

In this study, a general PV model is built and implemented using MATLAB/SIMULINK to verify the nonlinear output characteristics for the PV module. The proposed model is implemented, as shown in Fig. 4. In this model, whereas the inputs are the solar irradiation and cell temperature, the outputs are the photovoltaic voltage and current. The PV models parameters are usually extracted from the manufactures data sheet.

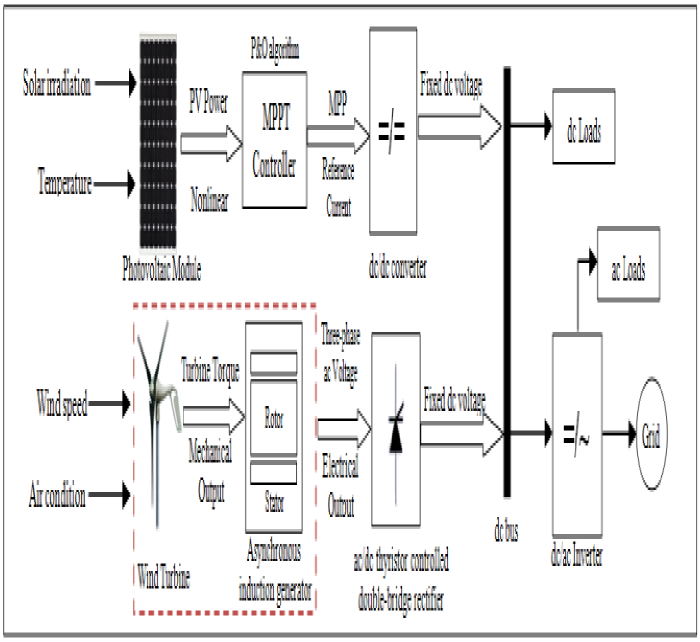


Fig. 4. Block diagram of the proposed system

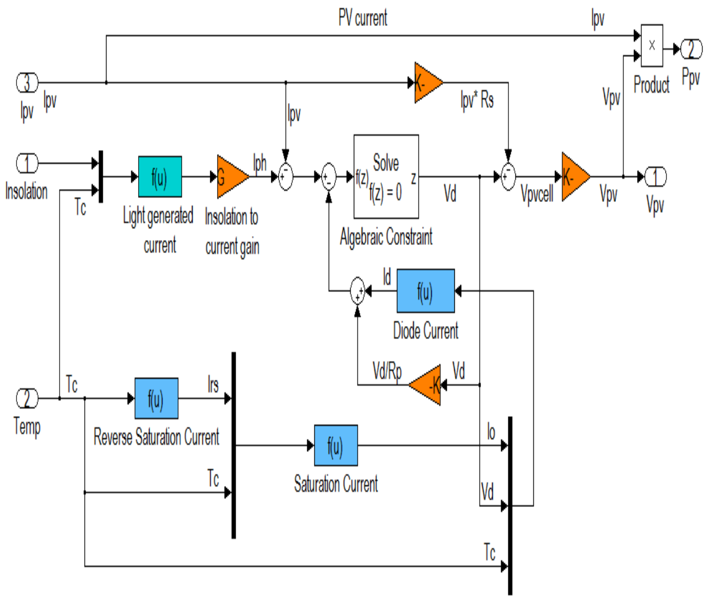


Fig.5 Subsystem implementation of the PV model

B. Modeling and Design of a WT and Induction Generator

Several studies have been reported regarding to WT andwind generators [14]. In this study, the proposed WT model is based on the wind speed versus WT output power characteristics. The output power of the wind turbine is given by [15]:

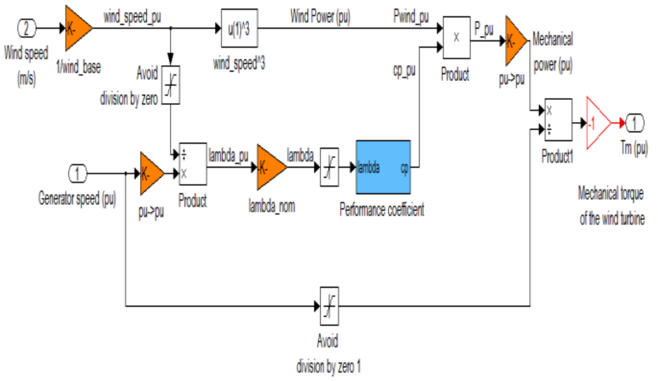
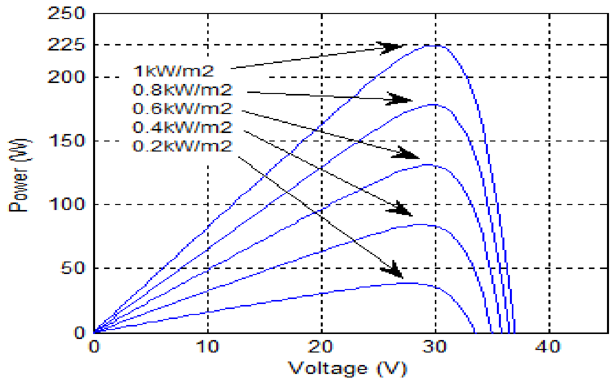


Fig.6. Subsystem implementation of the WT model

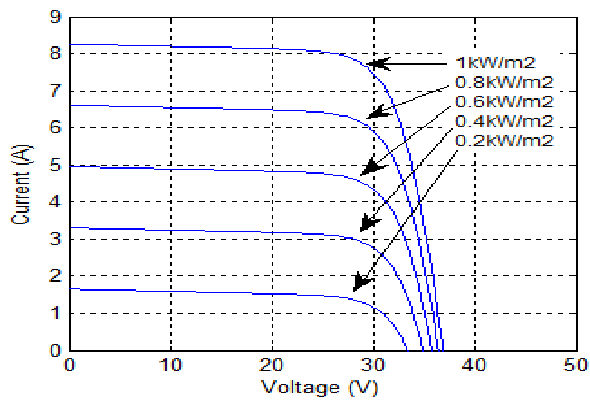
The wind turbine induction generator (WTIG) model isdesigned using the built-in Sims Power System library. The rotor shaft is driven by the WT which produces the mechanical torque according to the generator and wind speed values. The electrical power output of the generator (stator winding) is connected to the smart grid. That might be possible in the future, because PV is projected to continue its current cost reductions for the next decades and be able to compete with fossil fuel. Some noted think-tanks recommend that India should adopt a policy of developing solar power as a dominant component of the renewable energy mix, since being a densely populated in the sunny tropical belt, the subcontinent has the ideal combination of both high solar insolation and therefore a big potential consumer base density. In one of the analyzed scenarios, India can make renewable resources such as solar the backbone of its economy by 2050, reining in its long-term carbon emissions without compromising its economic growth potential. The standalone solar photovoltaic energy system cannot provide reliable power during non-sunny days. The standalone wind system cannot meet the constant load demands due to significant fluctuations in the magnitude of wind speeds throughout the year. Therefore, energy storage systems will be required for each of these systems in order to satisfy the power demands. Usually storage System is expensive and the size has to be reduced to a minimum possible for the renewable energy system to be cost effective. Hybrid power systems can also be used to reduce energy storage requirements. By integrating and optimizing the solar photovoltaic and wind systems, the reliability of the systems can be improved and the unit cost of power can be minimized. In India the Solar-Wind Hybrid power plants are technically approved by the Ministry of New and Renewable Energy (MNRE). These Solar / Wind Hybrid power plants generate electricity and can be an alternate source for the costly diesel generators which are run during the power cuts and also in locations where continuous EB supply is not available. The Returns on Investment (ROI) of these projects are very less and also with the Central Financial Assistance provided by the governments it is much faster. With these systems we can generate, store and use the power as and when required and also for rural electrification.

III. SIMULATION RESULTS AND DISCUSSION

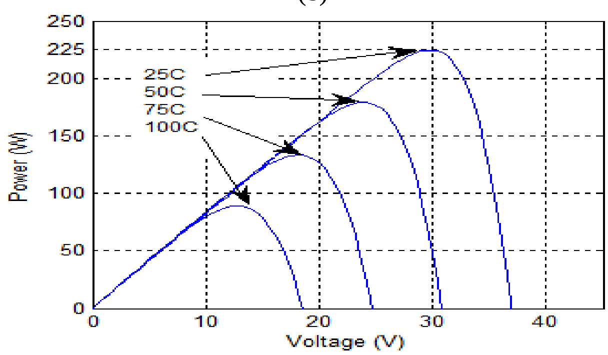
The block diagram of the integrated photovoltaic/wind turbine system, and the power controllers are shown in Fig. 2.The major inputs for the proposed PV model were solar irradiation, PV panel temperature and PV manufacturing data sheet information's.TheI-V and P-V output characteristics for the PV model are shown in Fig.6. The output power and current of PV module depend on the solar irradiance and temperature, and cell's terminal operating voltage as well. It was found from Fig. 6(a) and 6(b) that with increased solar irradiance there is an increase in both the maximum power output and the short circuit current. On the other hand, we observe from Fig. 6(c) and 6(d) that with an increase in the cell temperature, the maximum power output decreases whilst the short circuit current increases



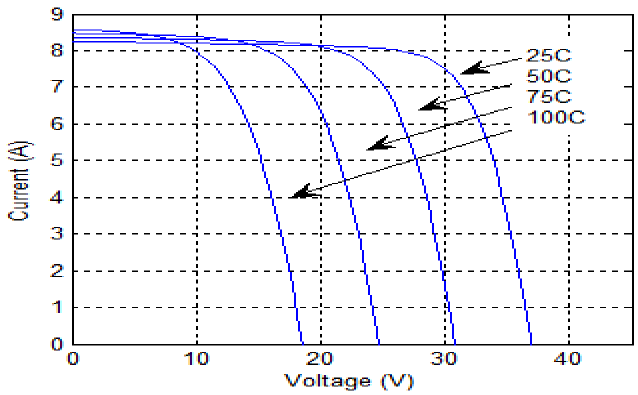
(a)



(b)



(c)



(d)

Fig.6. I-V and P-V output characteristics (a - b) with different *G* (c - d) with Different *Tc*

IV. CONCLUSIONS

In this paper, a novel PV/WT hybrid power system is designed and modeled for smart grid applications. The developed algorithm comprises system components and an appropriate power flow controller. The model has been implemented using the MATLAB/SIMULINK software package, and designed with a dialog box like those used in the SIMULINK block libraries. The available power from the PV system is highly dependent on solar radiation. To overcome this deficiency of the PV system, the PV module was integrated with the wind turbine system. The dynamic behavior of the proposed model is examined under different operating conditions. Solar irradiance, temperature and wind speed data is gathered from a 28.8kW grid connected solar power system located in central Manchester. The developed system and its control strategy exhibit excellent performance for the simulation of a complete day. The proposed model offers a proper tool for smart grid performance optimization.

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