Isolated Wind-Solar Hybrid Power Generation System with Battery Storage

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Abstract: The energy need of the world has been met mostly by fossil base fuels. For this reason, countries increasingly depend on such fuels. Each year millions of tons of greenhouse gases (GHGs) are being emitted from fossil fuel based power plants. In this paper, a battery-supported hybrid wind-solar energy generation system with switching power flow control is presented to supply stable electrical power.

Keywords: Hybrid power generation, energy management strategy, battery storage

I. INTRODUCTION

According to recent scientific literacy works [11], about 78–80% of the world commercial energy comes from fossil fuels, such as, petroleum, coal and natural gas. Those high-carbon sources have negative effects in our environments, such as, effects on heath, land, air and rain. In view of that, the attention of most countries around the globe has been shifted to low-carbon energy. Renewable energy is naturally abundant resources, which can be harnessed without compromising future energy needs. Unlike fossil fuels, this depletes as time goes on. Renewable energy sources like wind, solar, biomass wave and tidal are abundant sources that can produce clean energy. On recent time, series of renewable energy technology improvement has been witnessed, because the cost of generating electrical power is decreasing.

Although, renewable energy is considered as the new technology of generating electricity, the barrier associated with renewable is stochastic and unpredictable weather behavior. Its availability varies depending on the location. That is why, it is necessary to complement renewable with other sources like batteries. Because of this intermittent nature of renewable, single renewable energy source tends to be problematic in terms of energy yield and operational cost. Based on the aforementioned drawbacks, two or more renewable are being combined to form a hybrid renewable energy system (HRES). The main goal of doing this, or to improve electrical power production, to minimize cost, to reduce negative effects associated with burning fossil fuels and to improve the overall system efficiency.

In recent times, the integrated renewable energy system is gaining more attention, because a hybridized system can be efficiently applied to supply high efficiency and reliable electricity to the end-users, unlike a single-renewable source. A HERS can be applied in stand-alone or grid-connected modes. Stand-alone system must have a large storage to handle the load. While in a grid-connected mode, the storage can be small, and the deficient power can be acquired from the grid. It should be noted that, grid-connected mode must have a power electronic controllers for load sharing, voltage, harmonic, and frequency control. Thus HERS operating model is classified into Island mode where the generated electricity is consumed locally and grid connected mode where the renewable energy source is connected to the grid.

600W 3-phase permanent magnet synchronous generator (PMSG) based on the wind power generation system (WPGS) and the solar power generation system (SPGS) consisting of 190W 3 pieces mono crystal solar panel were combined to build a 1170W hybrid wind-solar power generation system (HWSPGS). The solar and wind power generation systems were used as the main energy sources while 100 Ah 12V 6 pieces gel jeep cycle accumulator groups were used as the energy storage device to ensure continuity of energy. Also dynamic modeling and switching power flow control of the battery supported the HWSPGS were performed using Matlab/Simulink. Determining the switching positions of the charge control unit according to loading and battery charge situations of the HWSPGS, power flow control between the generation unit and consumer was made in planned manner.

The hybrid power generation systems are installed through parallel connection of two or more conventional and renewable energy generation systems to each other. The hybrid power generation systems are one of the best solution methods to meet the electric energy need of mini or micro networks far distance from energy generation and distribution centers and of small settlement units. Most commonly, the wind-solar hybrid power generation system is used. For electric generation systems in various structures, recently, hybrid energy generation systems are realized by combining mainly the wind and the solar energy and fuel cell and soon. However, as more staff will be used for hybrid energy generation systems installed with more than one renewable energy source, the cost and installation area need will increase and structure and inspection of the system will become complicated

In this paper, a battery-supported hybrid wind-solar energy generation system with switching power flow control is presented to supply stable electrical power to two laboratories at the Electric & Electronic Engineering Department.

II. LITERATURE SURVEY

In [1], a battery-supported hybrid wind-solar energy generation system with switching power flow control is presented to supply stable electrical power to two laboratories at the Electric & Electronic Engineering Department. For this purpose, 600W 3-phase permanent magnet synchronous generator (PMSG) based on the wind power generation system (WPGS) and the solar power generation system (SPGS) consisting of 190W 3 pieces mono crystal solar panel were combined to build a 1170W hybrid wind-solar power generation system (HWSPGS). The solar and wind power generation systems were used as the main energy sources while 100 Ah 12V 6 pieces gel jeep cycle accumulator groups were used as the energy storage device to ensure continuity of energy. Also dynamic modeling and switching power flow control of the battery supported the HWSPGS were performed using Matlab/Simulink in this study.

In order to meet the load demand in island micro-grid, "Research on optimal capacity configuration for distributed generation of island micro-grid with wind/solar/battery/diesel engine" [2] proposed the operation and control strategy of the isolated micro-grid system with wind/solar/battery/diesel engine based on the analysis of the basic characteristics of every distributed generation in the system. The corresponding mathematical model was built on the objective functions of minimizing the system total cost and maximizing the power supply reliability and it is constrained by the system power balance and the distributed generation output. The mathematical analytic method was adopted to optimize the number of every distributed generation in the micro-grid. The simulation was conducted on an island using the proposed model to obtain the optimal capacity configuration for distributed generation of the micro-grid, proving the model effective.

An optimization method proposed in [3] that takes economic and technical indexes into account, which optimize the capacity of the battery and diesel generators under the premise of satisfying the technical indexes, and also optimize capacity of wind turbine (WT) and photovoltaic array (PV) by considering the economic index. Among them, the economic index of the system is to minimize the life-cycle cost (LCC). According to the wind-solar resources of the installed site, the mathematical model of the system is built after analyzing the output characteristics of each micro-source and the energy dispatching strategy. Finally, the particle swarm optimization (PSO) algorithm is adopted to obtain the minimum cost and the optimal capacity configuration scheme by MATLAB simulation software. The influence of capacity of WT and PV on LCC is analyzed too.

"The Constrained-Network Propagation (C-NetP) Technique to Improve SBAS-DInSAR Deformation Time Series Retrieval" [4] proposed a roadside unit (RSU)-coordinated synchronous multi-channel medium access control (MAC) scheme for vehicular ad hoc networks (VANETs). The proposed scheme allows the on board unit (OBU) to reserve service channels (SCHs) on the control channel (CCH) during almost the whole synchronous interval and supports simultaneous transmissions on different SCHs. It enhances the performance of VANETs and decreases the CCH congestion. Moreover, we use RSU to record the rendezvous information and broadcast it to the OBUs. This method avoids the multi-channel hidden terminal problem. An analytical model is developed to evaluate the aggregate throughput on SCHs. This model considers the following factors: non-safety message transmission probability in each synchronous interval, average size of the non-safety message, and the number of OBUs. Furthermore, the requirement of obtaining the maximum throughput is computed. Simulation results are provided to validate the analytical model and to demonstrate the improvement in throughput. The results indicate that the proposed scheme can provide

higher aggregate throughput than that of the vehicular enhanced multi-channel MAC and IEEE 1609.4, and better performance in CCH congestion control especially under high network load conditions.

Gupta, Ankit et al [5] presented an innovative region-growing-based technique that permits to improve the surface displacement timeseries retrieval capability of the two-scale Small BAseline Subset (SBAS) Differential Interferometric Synthetic Aperture Radar (DInSAR) approach in medium-to-low coherence regions. Starting from a sequence of multitemporal differential SAR interferograms, computed at the full spatial resolution scale, the developed method "propagates" the information on the deformation relevant to a set of high coherent SAR pixels [referred to as source pixels (SPs)], in correspondence to which SBAS-DInSAR deformation measurements have previously been estimated, to their less coherent neighbouring ones. In this framework, a minimum-norm constrained optimization problem, relying on the use of constrained Delaunay triangulations (CDTs), is solved, where the constraints represent the displacement values at the SP locations. Such DInSAR processing scheme, referred to as Constrained-Network Propagation (C-NetP), is easy to implement and, although specifically developed to work within the two-scale SBAS framework, it can be extended to wider DInSAR scenarios. The validity of the method has been investigated by processing a SAR dataset acquired over the city of Rome (Italy) by the Cosmo-SkyMed constellation from July 2010 to October 2012. The achieved results demonstrate that the proposed C-NetP method is capable to significantly increase the spatial density of the SBAS-DInSAR measurements, reaching an improvement of about 250%. Such an improvement allows revealing deformation patterns that are partially or completely hidden, by applying the conventional twoscale SBAS processing. This is particularly relevant in urban areas where the assessment and management of the risk associated to the deformation affecting infrastructures is strategic for decision makers and local authorities.

In [6], Gupta, Ankit et al presented an extensive review and tutorial on quantum search algorithms (QSA) and their potential applications, and we employ a QSA that finds the minimum of a function in order to perform optimal hard MUD with a quadratic reduction in the computational complexity when compared to that of the ML MUD. Furthermore, we follow a quantum approach to achieve the same performance as the optimal soft-input soft-output classic detectors by replacing them with a quantum algorithm, which estimates the weighted sum of a function's evaluations. We propose a soft-input soft-output quantum-assisted MUD (QMUD) scheme, which is the quantum-domain equivalent of the ML MUD. We then demonstrate its application using the design example of a direct-sequence code division multiple access system employing bit-interleaved coded modulation relying on iterative decoding, and compare it with the optimal ML MUD in terms of its performance and complexity. Both our extrinsic information transfer charts and bit error ratio curves show that the performance of the proposed QMUD and that of th

"Exploiting the Operational Flexibility of Wind Integrated Hybrid AC/DC Power Systems" [7] proposed to exploit potential flexibility by controlling power flows through HVDC by the merits of its flexible regulation capability, as well as HVAC transmission switching (TS). To synergistically schedule them with generator units, a security-constrained economic dispatch (SCED) model for wind integrated hybrid AC/DC power system is presented to realize the co-optimization of generation and TS. Wherein, multiple uncertainties (wind power fluctuation and generator failure) are considered, and the linear power flow model of the DC grid is adopted. Then the model is transformed into a two-stage (normal state optimization and corrective dispatch verification) robust optimization (RO) model for iterative solution by the aid of the column-and-constraint generation (C&CG) algorithm. Case studies on the modified IEEE 14-bus and IEEE 118-bus systems show that TS can assist HVDC to optimize power flow distribution and provide more flexibility, meanwhile optimizing HVDC transmission power and TS can greatly reduce the operating cost of the whole system.

Dawei Zhao et al [8] proposed the UHVDC project from a practical renewable energy base to load centres in China is chosen as an example, the actual structure and parameters are used to establish a typical example system for AC/DC hybrid power grid with high-proportion renewable energy. The new generation synchronous condenser with large capacity and the supporting synchronous generators are all considered. First, the installed power generation, power grid structure, and load configuration of example system are introduced. Then the load flow distribution and transient stability characteristics are analysed by using DIgSILENT Power Factory software. Finally, the feasibility of the proposed example system is shown by simulation results.

"Internet of Robotic Things: Concept, Technologies, and Challenges" [9] proposed a new concept which tackles the issues for supporting control and monitoring activities at deployment sites and industrial automations, where intelligent things can monitor peripheral events, induce sensor data acquired from a variety of sources, use ad hoc, local, and distributed ''machine intelligence'' to determine appropriate course of actions, and then act to control or disseminate static or dynamic position aware robotic things in the physical world through a seamless manner by providing a means for utilizing them as Internet of robotic things (IoRT). Although progressive advancements can be seen in multi-robotic systems, robots are constantly getting enriched by easier developmental functionalities, such vertical robotic service centric silos are not enough for continuously and seamlessly supporting for which they are meant. In this paper, a novel concept—IoRT is presented that highlights architectural principles, vital characteristics, as well as research challenges. The aim of this paper is to provide a better understanding of the architectural assimilation of IoRT and identify important research directions on this term.

The unique standalone hybrid power generation system proposed in [10], applying advanced power control techniques feed to power sources; Wind power, solar power, storage battery. The objectives of the advanced power control techniques are to satisfy the load power demand and, to maintain the state of charge of the battery bank to prevent blackout and to extend the life of the batteries. The variable voltage and frequency of a generator is first rectified and controlled by a DC/DC converter before being fed to a common DC bus. The variable output voltage of the photovoltaic module is also controlled by a DC/DC converter. The DC bus collects the total power from the wind and photovoltaic systems and uses it partly to supply the required load demand and partly to charge the battery bank. Similarly the development of the active reactive power and dump power control is considered. The result of simulation revealed that amplitude and phase of AC output voltage where well regulated in the proposed hybrid system. It is anticipated that this hybrid power generation system by natural energy is incorporated, will contribute to global environmental protection on isolated islands and rural location. The system has been developed to supply power for telecommunications equipment in areas with no commercial power source.

III. SYSTEM DESIGN

The working strategy of the switched controller is within the framework of 6 rules as it can be understood from the flow diagram in Fig. 8, and it shows the energy management strategy of the charge control unit in detail depending on the system loading, generation and battery charge conditions.

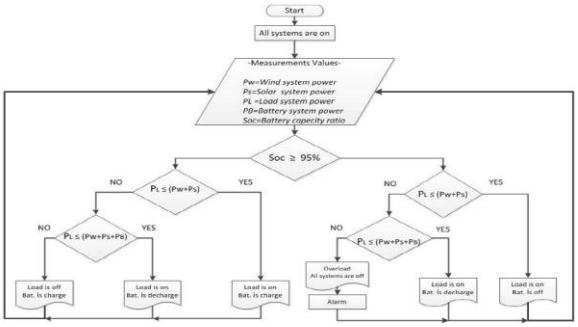

Fig.1 Flow diagram of energy management strategy

The six rules determined for efficient and effective use of energy are given below in detail.

a) If the battery charge rate is more than 95% and consumed power is smaller than the total generated power, receiver is powered directly through the wind-solar hybrid power generation system after the battery is deactivated.
b) If the battery charge rate is more than 95%, and the consumed power is higher than the total generated power but smaller than the total power generated with battery, receiver is powered with battery power after all the system is activated.
c) If the battery charge rate is more than 95%, and consumed power is higher than the total generated power and power stored in the battery, this means that excessive load is connected. All the systems must be deactivated.
d) If the battery charge rate is less than 95%, and consumed power is smaller than the total generated power, the receiver is powered by being activated and surplus power is stored in the battery.
e) If the battery charge rate is less than 95%, and consumed power is higher than the total generated power but smaller than the total power generated with battery power, the battery must be passed to discharge position by activating the receiver.
f) If the battery charge rate is less than 95%, and consumed power is higher than the total generated power and the total power stored in the battery, this

means that excessive load is connected. The load must be deactivated, and it must be charged by activating the battery as it is not full charged.

The main reasons why such a control strategy for the hybrid power generation system has been developed are to increase the efficiency of system by making energy flow control, prevent shortening of battery life and protect the system and receiver against the excessive loading conditions. As a matter of fact, the power generally generated in small power hybrid power generation systems is directly sent to the battery group, and receivers are powered on battery group. However, this condition increases the risk for the battery to be excessively charged or discharged, and it also decreases its lifetime. Unfortunately, energy generated in the installed real-time system is directly sent to the storing units and receivers are powered on them. The cost of batteries constitutes an important part of the system cost. Additionally, when an excessive load is connected to the system, the system elements may be damaged because of the excessive discharge and excessive current drawn from the battery group. In an ideal system, the power needed by the receiver must be directly sent to the receiver to power it up, and if there is surplus generated power, it must be stored in the battery depending on its charge condition.

IV. RESULTS AND DISCUSSION

To calculate current flowing through PV cells, mathematical model is state in this section. Different current constitute and factors are considered. Current flowing solar cell is given as:

$$\boldsymbol{I_{ph} = [I_{sc} + k(T - 298)] \times {I_r}/{100}}$$

Where,

- I_{ph} =photo current
- I_{sc} = short circuit current
- k = short circuit current of cell at 25˚C and 1000 w/m^2
- T = operating temperature (˚K)
- I_r= solar radiation (w/m^2)

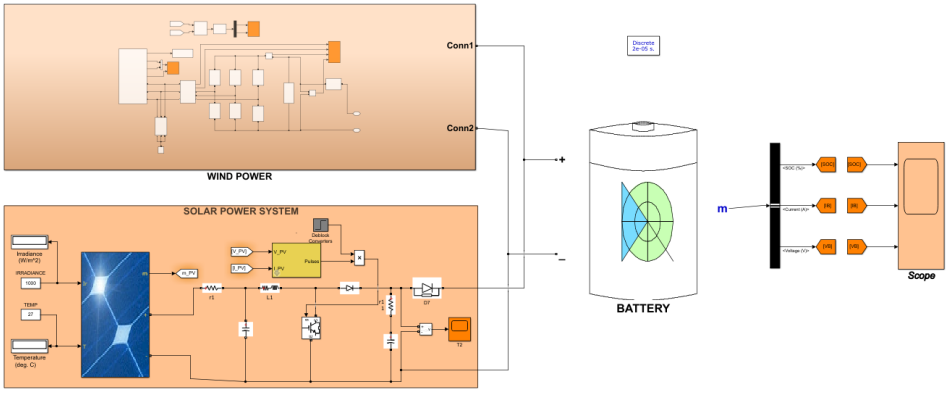

Fig 2 simulation diagram

The simulation diagram (shown in figure 2) consists of a wind power system combined with a solar power system. The ground of both systems is connected and given to the ground terminal of the battery. The battery is charged by both wind power sources and a solar power source. Oscilloscope draws waveform of all three, wind system, solar system, and battery. Solar panel voltage is shown in fig 3. Initially there is spike in voltage but later it become stable approximately 27.5 Volt.

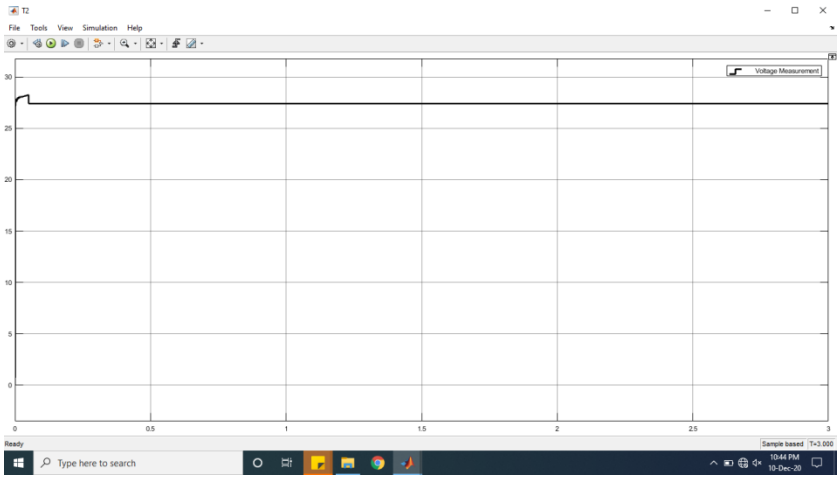

Fig 3 Solar panel voltage

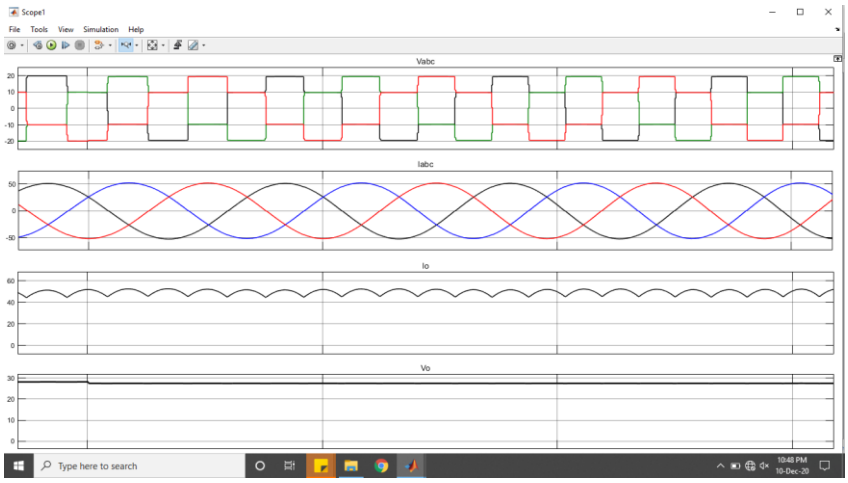

Fig 4 Wind energy

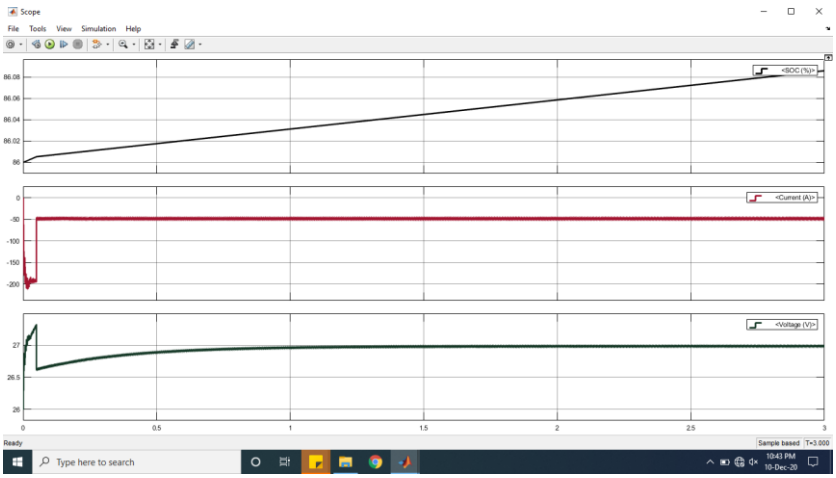

Fig 5 battery charging

The waveform for wind energy source is shown in fig 4. Input voltage ($Vabc$) is square wave (-20V to 20V) whereas output from wind system (V_o) is 27.5V. The input current (I_{abc}) and output current (I_o) are also shown in fig. fig 5 shows waveform of battery (voltage, current of battery and SOC).

Wind offers less distortion while solar offers high power value because of MPPT protocol. Therefore

we combine both systems for high power less distortion output. Advantages of proposed system over previously studied systems [1-10] are:

- This system requires fewer components for AC to DC conversion compared to systems discussed in previous papers.
- It took less time for charging a battery.

Table 1 shows difference between charging time of proposed system with other systems. It is clearly shown that charging time taken by hybrid system (solar + wind) is less compared to solar or wind alone. The graph (fig 6) shows proposed system requires even less charging time compared to other existing hybrid system.

Table 1 time required by different system for charging battery

Sr. no.	System used for power generation	Time taken (min)
1	Solar generated power	235 min
2	Wind power system	185 min
3	Hybrid system	114 min
4	Proposed system	98 min

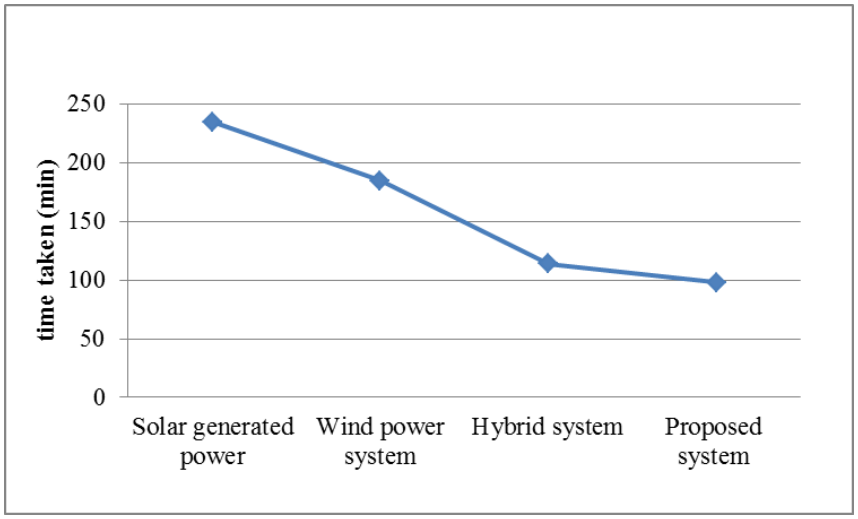

Fig 6 graph showing time taken by different system to battery

V. CONCLUSION

The application of studies made for energy control directly on real systems may cause occurrence of various unfavourable conditions. Mainly, conditions that give damage to the system elements and the most importantly to the human life have occurred. For this reason, making of exact simulation model of the system to be controlled and then applying control on the simulation primarily will conserve the system elements and human life first and foremost.

In this study, by considering such negative conditions, a real-time modeling of the installed wind-solar hybrid power generation system and energy flow controller to eliminate the troubles in systems were designed. When dealt with the curves obtained from the simulation results, it is seen that there are not big differences in the electrical and mechanical magnitudes in parallel to dynamic behaviour of the installed hybrid power generation system. Besides, by exactly comparing the data obtained from the real system with the data obtained from the simulation study, it has been reached the conclusion that accuracy rating of the simulation study realized related to the hybrid power generation system is correct. As a matter of fact, it is seen from the simulation results that the controller designed for energy flow control operates with a very good performance. According to the simulation results, troubles that might occur in energy flow have been eliminated with the switched controller developed. The battery group is activated and deactivated according to behaviors of the system in loading condition. In this manner, decrease in lifetime of the battery is prevented. This decreases the maintenance cost of the system. Moreover, the system is protected against the excessive loading conditions.

In the future, thanks to the installed hybrid power generation system, students at electric department will

be able to carry out studies on the simulation model instead of studying on the real-time system by taking risk on subjects such as electric generation with renewable energy systems, system control and efficiency of generated energy and soon. In this way, they will develop the new energy control methods and test the controllers they develop on the simulation without any risk so that, will be able to make their applications safely on a real system.

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