A LabVIEW Model For the Operation and Control Strategy of a Hybrid System

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Abstract

Due to the varying nature of the load demand and the fluctuating power supplies by a renewable energy system, a decision-making strategy to operate and control a hybrid system is considered. The proposed hybrid system is comprised of PV/wind and diesel units with battery backup. The aim is to ensure high operational battery bank, running diesel units in their most efficient operational ranges and maximizing the utilization of the renewable energy sources. A *LabVIEW* model is designed whereby the hybrid system components are simulated as virtual instruments [VI] interacted with functional blocks. The PV/wind VI measure continuously the available power generated from the designed system capacity, and the functional VI compare this with the actual load demand over short periods. Consequently, a decision-making scheme is considered in which optimum operation of diesel units and battery banks is reached, and also whereby scenarios can be drawn for further prediction of system power flows and State-of Charge [SOC] of the battery bank.

Keywords: LabVIEW, Hybrid, Renewable Energy, Control, Virtual Instrument

1. INTRODUCTION

Today, the most common application of standalone hybrid system is that of diesel generator augmentation (FIGURE 1), where the renewable energy source such as PV or wind and the battery bank are sized to reduce the run-time and therefore fuel consumption of the diesel generators. These systems provide sufficient storage to allow the load to be shifted, therefore ensuring that the generator is always substantially loaded. Recall that engine-driven generators are inherently inefficient when operated at light loads; for example less than 40% which can shorten their life and increase maintenance costs. Further, the hybrid system formed by the combining of renewable and conventional energy sources with a battery bank of storage, avoids the need for a spinning reserve which is the extra rotating capacity on line to overcome sudden load surges, and thus decreasing their fuel efficiency. In the same time, it provides an economic and reliable supply of electricity with reduced Loss of Load Probability LLP, especially when the daily load demand is highly variable with a ratio of peak load to minimum load of 3 or more.

On the other hand, the sizing of this hybrid system, which is based on solar radiation data for the site, load profile and back-up supplements, doesn't guarantee supply continuity or optimum operation. In addition, operational economics, which are used as constraints on the design may not necessary hold. This is due to the fact that radiation data and global irradiation are given in form of monthly averaged daily data for selected angles of panel inclinations are used. Annual load data is based, on the other hand, on number and hours of operation of appliances in the form of energy supplied in Wh/day and charge capacity in Ah/month, it's obvious that the annual load profile is different from the actual daily load profile.

Any mismatch between generation and load is usually taken out by battery storage mean. Thus, battery storage plays vital role in maintaining reliable and economical power supply. Yet, the daily/hourly cycling characteristics of battery have a pronounced effect on its lifetime as depicted in FIGURE 2

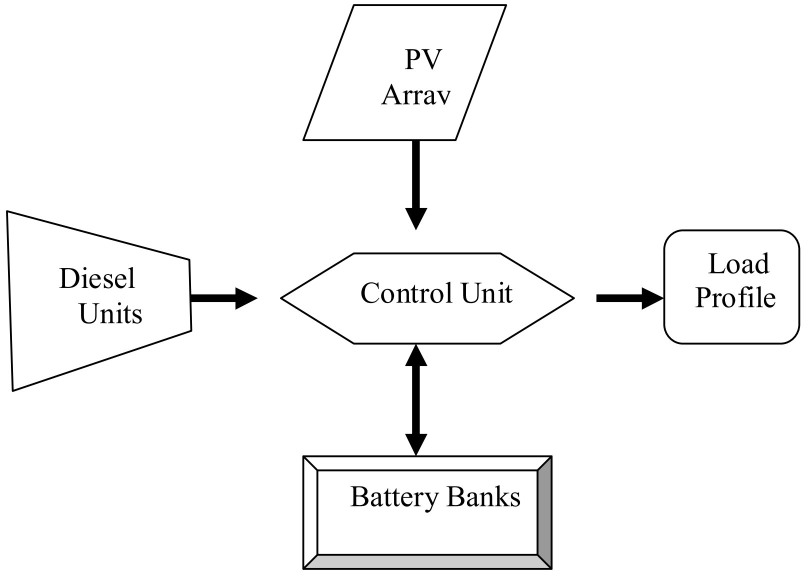


FIGURE 1: PV-diesel-battery Hybrid System

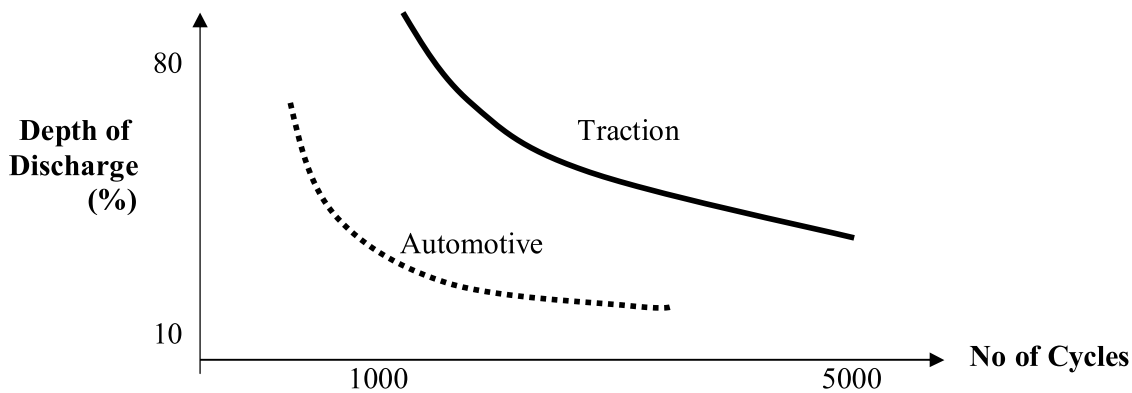


FIGURE 2: Battery lifetime in Terms of DOD and Number of Cycles

In order to ensure a continuous and optimum operation of this hybrid system, operational simulation is an essential tool to control the system in order to achieve optimum performance. Thus the goal is to prevent inefficient operation of diesel and "damping" of excess energy, reduce number of cycles and improves Depth-of-Discharge [DoD] for battery banks, maximize the utilization of PV and ensures high reliability LLP. It is to be here noted that due to varying nature of load demand, the fluctuating power supplied by PV and the resulting variation of battery State-of-Charge [SoC], the hybrid system has to respond continuously to these changing conditions.

A *LabVIEW* model is proposed to control the hybrid system by reading the hourly generation and load, either online or assumed and decide when switching diesel units on or off in order to alleviate battery cycling and improves DoD. The model continuously monitors hourly generation and load and displays status of battery bank and cycling as well as generation from different sources. It also displays warnings for malfunction. This model can be updated for modified site and load data.

2. MODES OF OPERATION

In order to propose a strategy of control for the standalone PV-diesel with battery bank system, one should analyze the different operating modes of such system over 24 hours of a typical day as shown in FIGURE 3. Typical load and generation profiles are assumed. Arbitrary units of rated capacities are used.

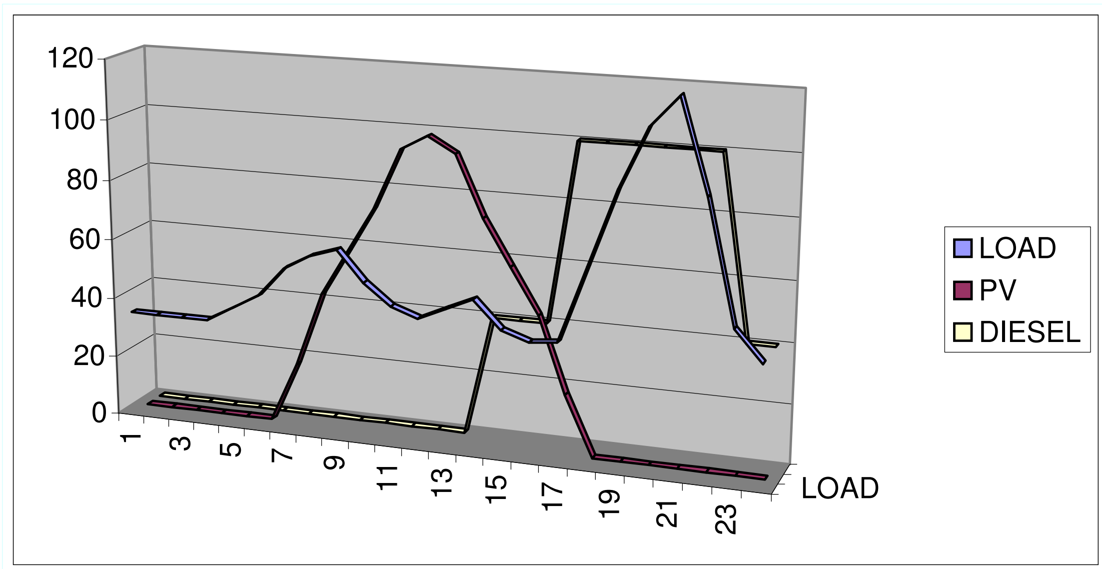


FIGURE 3: Operating modes for a PV-diesel-battery hybrid system

Mode I:
The base load, which is typically experienced at night-time and during the early morning hours, is supplied by energy storage in the battery. PV power is not available and the diesel generator is not normally started, but might be started to reduce battery DoD.

Mode II:
PV power is supplemented by stored energy to meet the medium load demand.

Mode III:
The medium load demand is supplied from PV. Excess energy is available from PV is stored in battery.

Mode IV:
The diesel generator is started and operated at its best efficiency power to meet the high evening load. Excess energy available from the diesel units is used to recharge the batteries.

Mode V:
The diesel generator power is increased to its maximum or nominal power to meet the high evening load. Again, excess energy available from the diesel units is used to recharge the batteries

Mode VI:
Diesel generator power is now sufficient to meet the peak load demand. Additional power is supplied from the battery.

Mode VII:
The diesel units power exceed the load demand, but it may be kept operational until the batteries are recharged to a high SoC.

In principle, most efficient operation is achieved if the generated power is supplied directly to load from source, which reduce cycling of battery banks. However, since diesel at light loads is inherently inefficient, it is common to operate diesel at its most efficient or maximum/nominal capacity and recharge battery from excess energy. Thus, with optimized cycling procedure of battery, long-term performance of the system is achieved. The selection for best strategy depends on fuel, maintenance, environmental aspects, etc.

3. SYSTEM ANALYSIS

In order to apply a control strategy, the following procedures are considered on individual system components:

1. Diesel Unit:
    (a) Once started, it should operate continuously for a minimum of 30 minutes to reduce engine wear and thus maintenance costs and stoppages
    (b) Not to allow to operate below a minimum of 40% to prevent low fuel efficiency and "glazing" on cylinder walls.

This is depicted in FIGURE 4

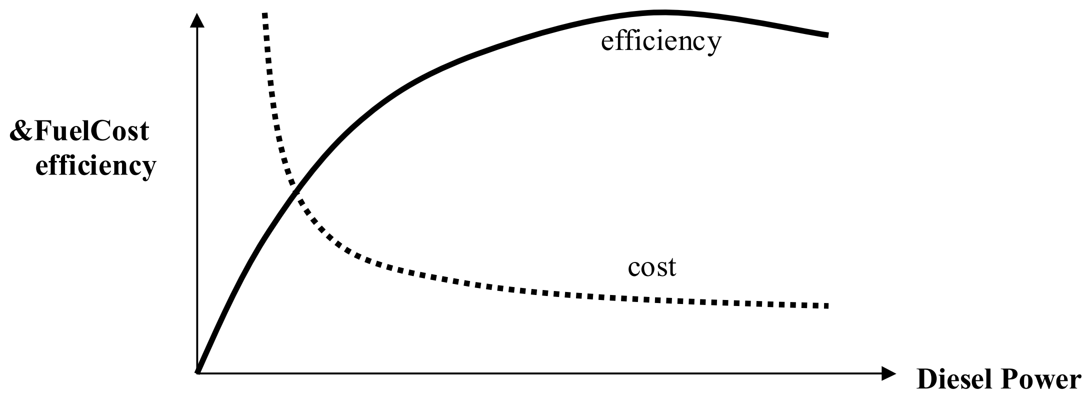


FIGURE 4: Fuel efficiency and cost of a diesel generator

2. Battery bank :
    In order to increase their lifetime, the following steps are considered:
    (a) A 70-80% SoC should be maintained.
    (b) A minimum DoD is maintained by controlling the number of cycling as shown in Fig()

3. PV Array:
    Here, the only consideration to apply is increasing supply reliability through Loss-of-Load-Probability LLP . Extra PV array or storage banks are added or removed according to the following figure:

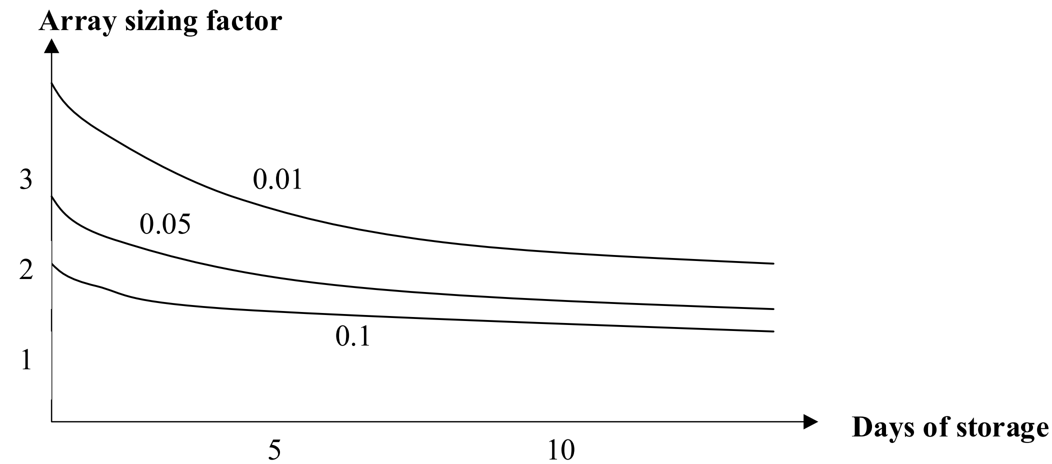


FIGURE 5: Sizing based on Loss-of-Load probability LLP

4. Load:
For a typical load profile (Fig. 6) generation is supplied by PV, diesel, battery or any of their combinations and switched off only when there is not enough generation according to thee overall strategy used in this study.
Percentage or rated capacity is assumed.

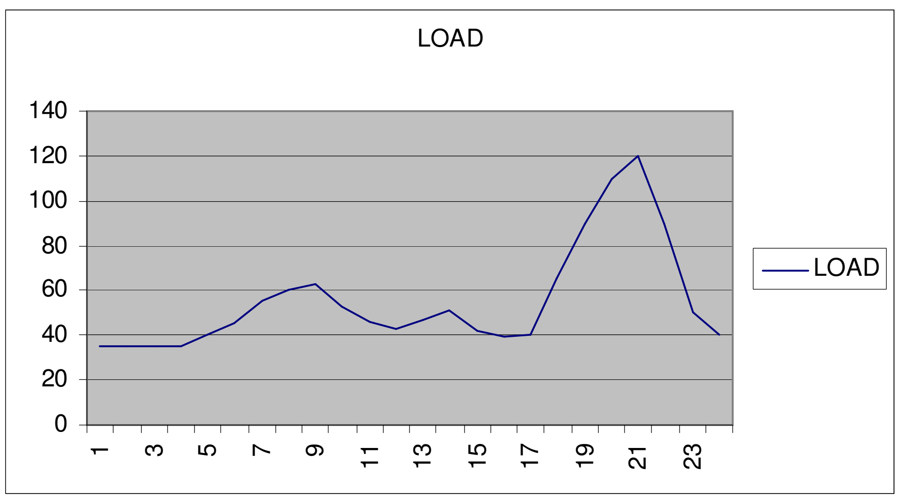
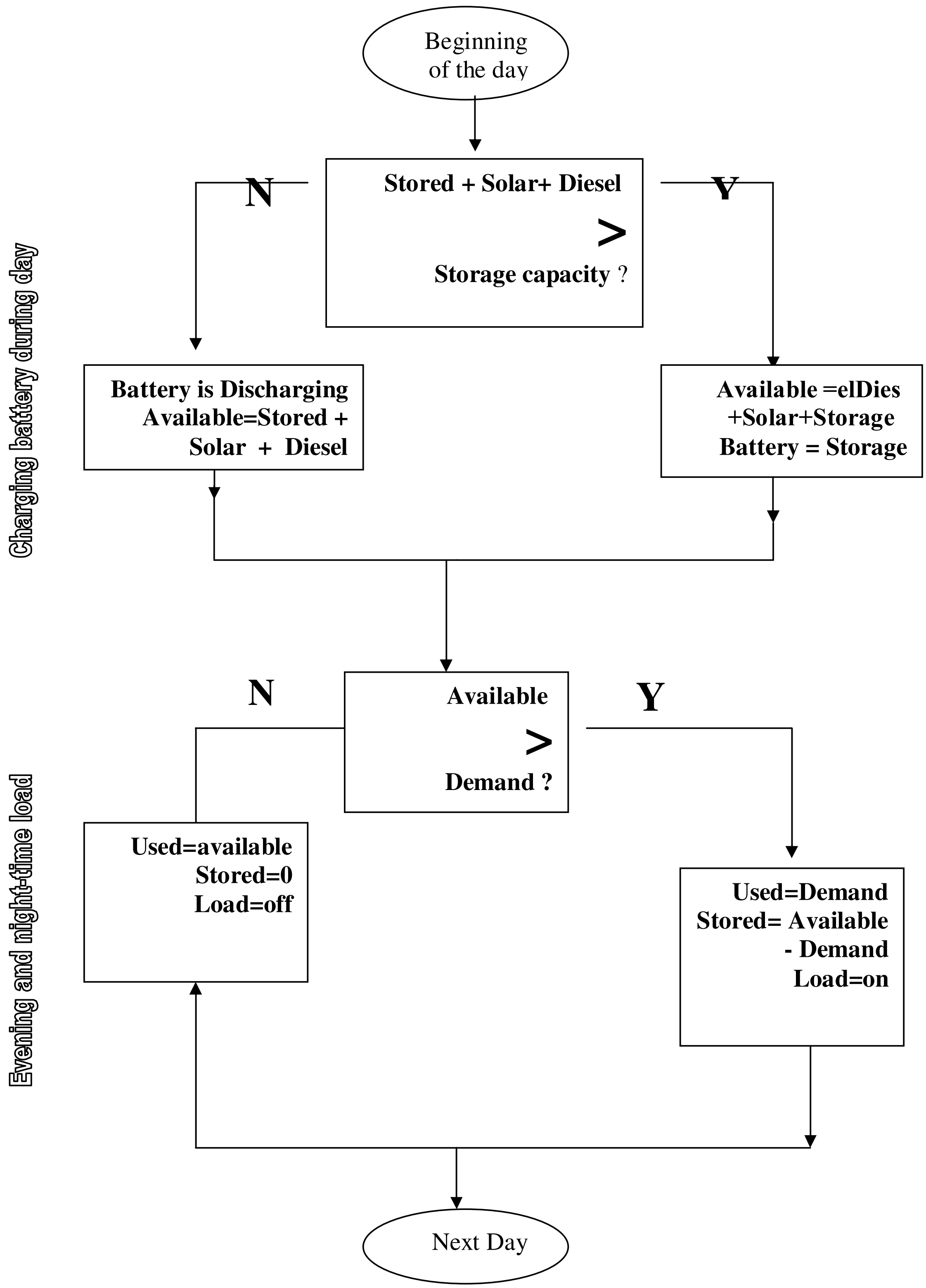


FIGURE 6:Typical load demand profile

5. Control & Monitoring Unit:
Once the storage capacity , PV panels and diesel units have been selected and sized, one must simulate numerically the operation of the system using hourly solar energy data and load demand in order to improve the reliability. The following flow chart outlines the procedure for controlling the system:



Hourly Energy Balance Flow Chart

4. LabVIEW MODEL

The model provide the following controls:

1. Automatic start/stop of diesel
2. Optimum loading of diesel
3. Charge limiting of PV when batteries are at high SoC and PV > load to prevent "gazing".
4. Possible disconnect load at low battery voltage and insufficient diesel to prevent excess battery discharge.
5. Continuous control of power flow
6. Load sharing
7. Monitoring of all the above. (See Control & Monitoring Unit)

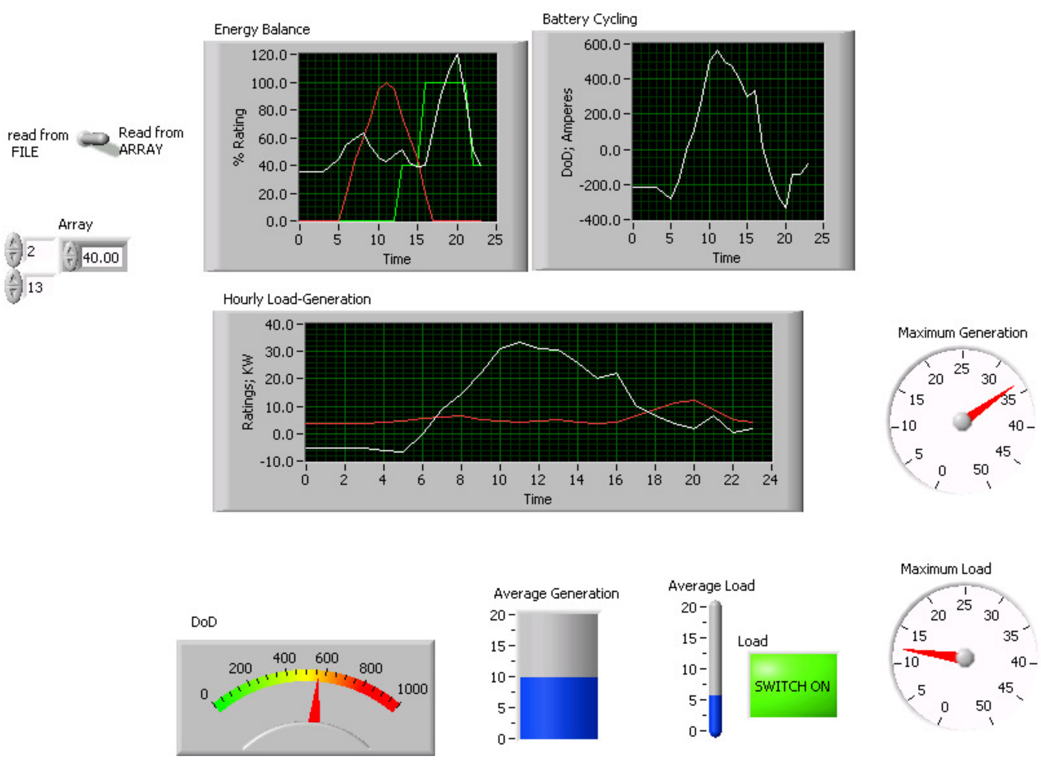


FIGURE 7: shows the Front Panel of *LabVIEW* model with different controls and monitors

It is assumed in this study that a 10KW PV array panel, 20 KVA diesel generator and 1000 Ah battery banks are used. An expected load of maximum 15 KW and typical profile are assumed. These data are calculated based on an adequate sizing. The source Block Diagram, which is used in the model can be made available on request by contacting the author.

Different generations/loads profiles are implemented in the form of 24 hours array data. Hourly display of different generating sources including battery charge/discharge, SoC battery cycling and DoD status are displayed. Load shedding can also be determined and displayed.

5. CONCLUSION

A control panel using *LabVIEW* is proposed and implemented on an already sized PV-diesel-battery hybrid system to operate diesel units, control battery DoD, monitor battery SoC and display hourly sharing of different generating sources. Thus, a more reliable and economical operation is achieved. The inputted data can be either direct measurement or in the form of pre assumed hourly array.

The model provides extra valuable means of controlling and monitoring a hybrid system with ease of updating for future developments. Other types of renewable energy systems such as wind of any combinations can be used in this system modeling.

6. REFERENCES

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