# Management of Solar power with Thermal power Generation Unit Using FPGA based Algorithm

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***Abstract*—Performance of solar Power generation units are totally depends on weather condition. In cloudy condition, the throughput of solar power house is affected. Thermal units will be consider as alternative to fulfill the energy gap. In this research Field Programmable Gate Array (FPGA) based algorithm is developed for the management of solar power shortage during cloudy and foggy weather condition. Algorithm take decision on the basis of less solar power throughput and arrange the alternative thermal resource using switching mechanism. Switching unit is operated by FPGA for the arrangement of alternate generator. In our consideration throughput is totally depends on the final power output of solar station.**

***Index Terms*—Field Programmable Gate Array (FPGA), Algorithm, Power management.**

## I. Introduction

As the population is increasing, demand of electrical energy exceeds from the capability to generate it. Also more usage of fossil fuel polluted the environment and cause the global warming. Solar power is an important source of green energy. In solar power, photo voltaic cells are used to convert light energy into electrical energy. But its output is not reliable and can change rapidly that can cause many issues for distribution system. Usage of energy storage devices i.e. batteries can somehow resolve this problem but still there are many challenges that has to be addressed for successful integration of solar energy into distribution system.

### A. Issue related to Inverter

As the output of photo voltaic cells is DC, means solar generators are capable enough to produce real power only and for the availability of reactive power, we have to operate an inverter at the output of these cells [10]. Some of the issue of Solar power generation are

- Lagging power factor
- Efficient absorbing reactive power
- Increase the amount of current.

### B. Problem of voltage fluctuation

As this mechanism is totally based on weather conditions, we can say that it has the capability to reduce the generation from its maximum ability to none and it can highly effect the consumers if steps have not been taken for compensate energy. In this scenario, battery can quickly provide power to minimize the interruption. The photo voltaic (PV) coupled battery energy storage system (BESS) that utilize the XP-Dynamic Power Resource (DPR) is the efficient solution of this issue [5]. BESS consist of a battery bank, control, inverting and protective circuitry and a transformer to maintain the voltage level. The output of photo voltaic cells is highly effected by clouds because of their responding time, when these are directly on the top, output becomes zero and when they move away, suddenly the cells start performing. The PV-coupled BESS can sense these voltage fluctuation and power on the battery bank for efficient transmission [1].

### C. Ramp Rate

As the problem of responding time of photo voltaic cells is discussed above, it also effects ramp rate that is normally specified by utility companies in kilowatts per minute (kW/min). But in the same XP-DPR, the ramp control algorithm continuously monitor the output of cells and command such that the output remains in the boundary defined by utility companies [1], [9].

### D. Frequency deviation

As the line frequency is 50-60 Hz, in the output of solar generator there is also deviation in frequency of 1-3 Hz. In wide area network, deviation of only 0.1 Hz can cause serious problems, so such frequency deviation can highly impact on load or may also be a risk of an accident [1]. When the frequency increased from the threshold value, BESS takes charge for any undesired event. Controlling of delivering and absorbing the power while stabilizing the frequency referred as Droop response that may also be known as Proportional controller with gain of 1/R, where R is defined as:

$$\%R = \frac{percent\ frequency\ change}{percent\ power\ output\ change} \times 100 \qquad (1)$$

As the BESS can deal with voltage fluctuation, ramp rate and frequency deviation successfully, it can also be used to improve the economic profile of distribution system depending upon local market rules and considerable things [8]. The Battery Energy Storage System (BESS) also find the solution for minimize the number of batteries and best location for the placement of the batteries that can reduce the fluctuation of voltage and improvise the active and reactive power in distribution system [1]. ”Optimal Sizing and Placement of Battery Energy Storage in distribution System Based on Solar Size for Voltage Regulation” [1]. So, the BESS makes the integration between solar generator and distribution system better by increased reliability and economically as well [1]. As the Smart grid concept is growing rapidly, this system can much improve in future and become helpful in many aspects. ”Battery Energy Storage for Enabling Integration of Distributed Solar Power Generation” [6], [13].

To supply the electrical power, a photo voltaic, wind turbine, fuel cell solar thermal collector system is designed by using Grid connected hybrid combined heat and power system. In considered cases it reduced the total cost of system. Combined Heat and Power (CHP) system is useful because heat and electricity are generated simultaneously that enhance reliability [6]. The Hybrid renewable energy system optimization is necessary for management of excess electrical and thermal energy. System operating cost can be reduced through utilization of such hybrid. ”Optimal Operation of a Grid-Connected Hybrid Renewable Energy System for Residential Applications” [13].

## II. PV BASED MICRO-GRID

Micro-grid maintain and monitor the power while supplying to the load [14]. Power management control strategy compensate the low voltages with the help of solar system and its storing capacity is also increasing[9]. Solar system and battery power inverters are used for grid-support and grid-forming [5]. Micro-grid main operation is to maintain energy balance while transmission and distribution. Different types of power inverters are used in Micro-grid according to the application. Management of power in solar PV and battery storage inverters are working in current control mode(CCM). Typical AC Micro-grid model can works on 400V and 50Hz [5].This Micro-grid model has two stages of power converters; DC to DC boost converters and DC to AC voltage source inverter. DC to DC boost power converters widely used in solar system. Battery bank plays important role in photo voltaic based Micro-grid network, where it efficiently stabilize the power. ”PV Based Microgrid with Grid-Support Grid-Forming Inverter Control-(Simulation and Analysis)”

## III. PROPOSED METHOD

Figure 1 show the basic idea of scenario of the project. It is clearly indicated that whole system is depends on FPGA. FPGA based algorithm can manage the distribution by take smart decision on the basis of Solar generation. To minimize the gap between the generation of the renewable resource at unfavorable condition, three alternative generators are available. Algorithm concern with the battery that charged by Photo Voltaic cells. Charging percentage of the battery is depends on different factors including voltage. Voltage is directly proportional to charging percentage as shown in figure 2. It is also clear that that minimal amount of decrease in voltage exponential decrease in charging. Orange region in graph show the threshold limit of the usability of the power utilization from batteries. Also red region show that unacceptable amount of voltage value, same as charging.

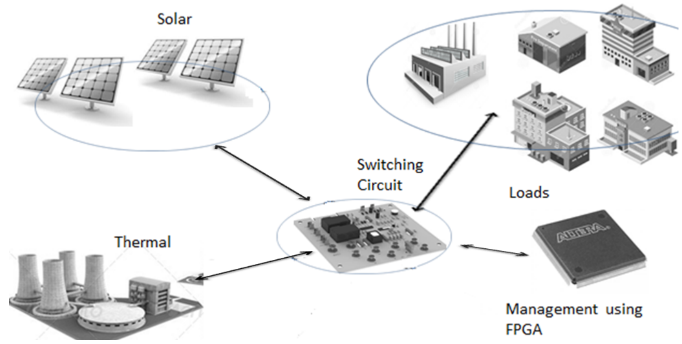


Fig. 1. Overall system diagram

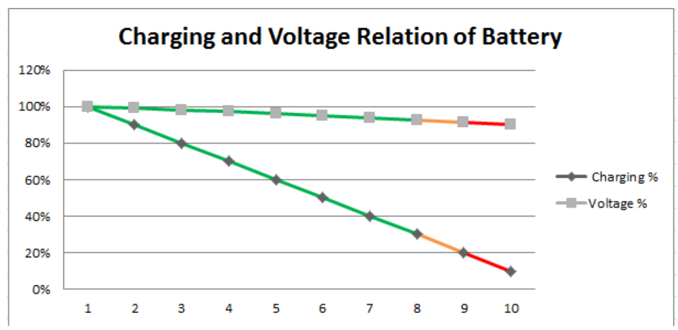


Fig. 2. Relation between voltage and charging

Proposed algorithm continuously monitor the state of battery. As it is know that solar is totally depend on weather, It is also important constrain that load in Sindh(Pakistan) region is maximum in day time. Algorithm is responsible for all of the load dependencies. Figure 3 shows the dependencies of load in 24 hour on Solar and thermal units [7]. Figure 3 also clearly indicates the in peak hours, solar provide maximum throughput. So it is possible of shift the dependencies totally on solar during day time. Figure 3 is our experimental consideration but it is feasible for all of the solar power based scenario, if implemented in Sindh province like regions [12].

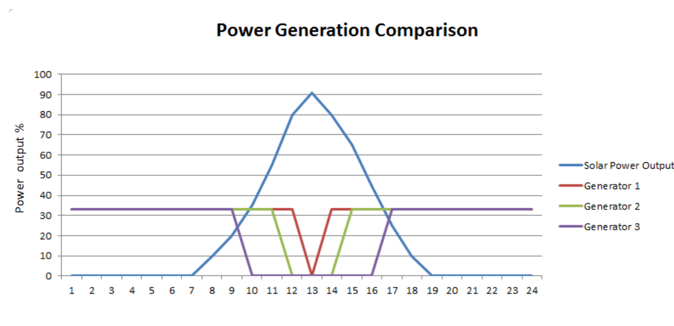


Fig. 3. Solar and thermal usage during 24 hours.

## IV. Implementation

This project is based on three different part. It include power source, circuit switching block, Altera FPGA module, and load bank. Figure 4 shows the Proteus simulation of the circuit connected at the output of battery, to generate the signal readable for FPGA. This circuit is important part of Circuit switching part of the system. All the decision taken by FPGA is controlled by circuit switching block.

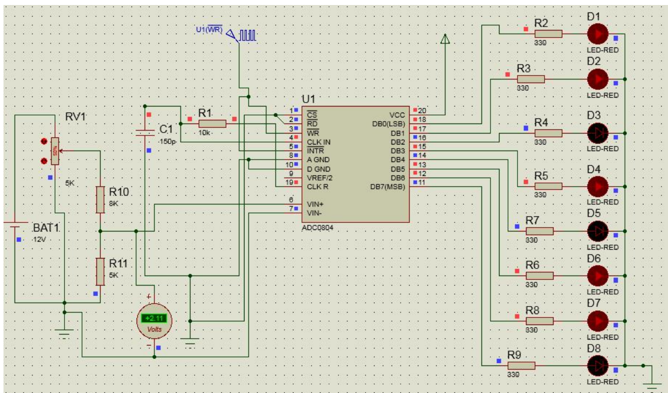


Fig. 4. Proteus Simulation.

On the basis of load requirement caused by the deficiency of solar power, algorithm will take the decision. Figure 5 show overall data flow diagram develop by Qurtus$II$ software during the implementation of power management algorithm. In this diagram $s$ is solar power deficiency input to the FPGA. After taking the decision, algorithm will send signal to the thermal generation units $g1$, $g2$, and $g3$.

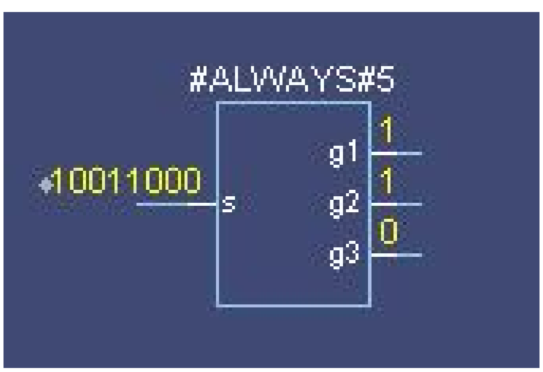


Fig. 5. Dataflow Structure.

As algorithm is fully depends on some input generated on the cause of solar deficiency, algorithm is fully based on decision blocks(switch case blocks). Figure 6 and 7 show the decision blocks and nested decision blocks of the algorithms. There are three decision blocks used in the implementation of algorithm as it has to control three generation unit. So it is rightly to say that decision blocks are proportional to the generation units.

$$D_\beta = K \times g \tag{2}$$

where $D_\beta$ is number of decision blocks, $g$ is number of generation units and $K = 1$.

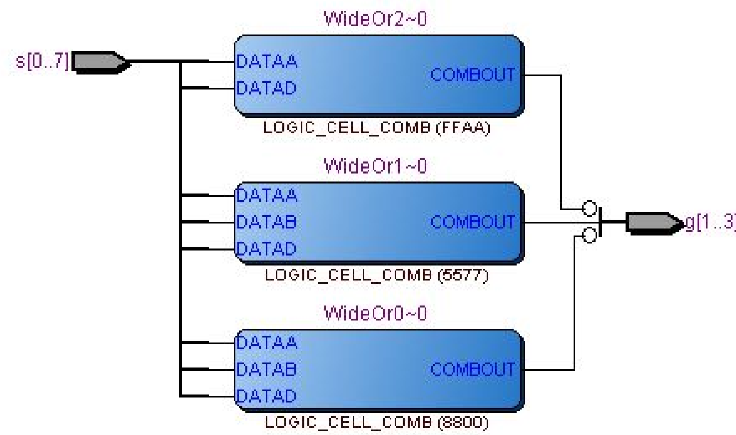


Fig. 6. Post fitting diagram based on decision blocks.

similarly each decision blocks contain 15 nested decision blocks. So algorithm complexity can be calculated by following equation.

$$g = 15 \times D_\beta. \tag{3}$$

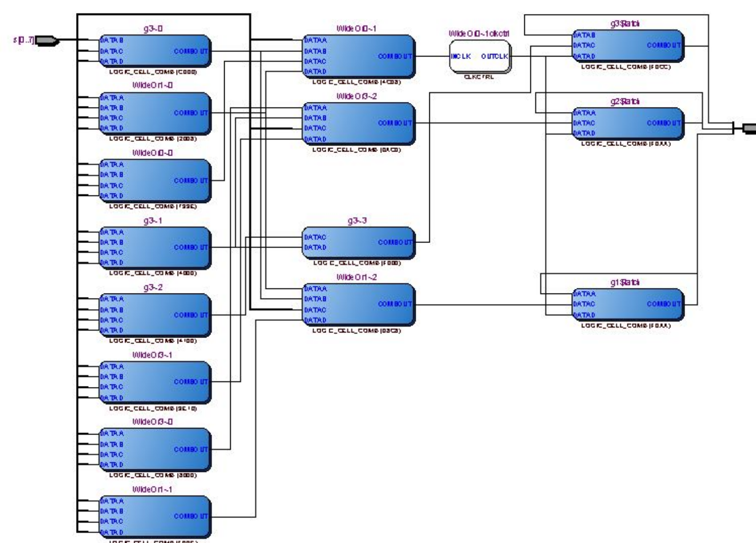

Fig. 7. Post fitting diagram based on nested decision blocks.

Similarly for FPGA internal resources Figure 8 shown the RTL diagram of power management algorithm. The complexity of resource utilization can be calculated by following equation.

$$R_u = \alpha_{D_{mux}} + \beta_{O_r} + \gamma_{D_{ff}} \tag{4}$$

Where $\alpha_{D_{mux}}$ is number of multiplexer used as a resource in FPGA, $\beta_{O_r}$ consider as number carry chain adders, and $\gamma_{D_{ff}}$

is number of flip flops used by algorithm. For this research the resource utilization complexity is eight.

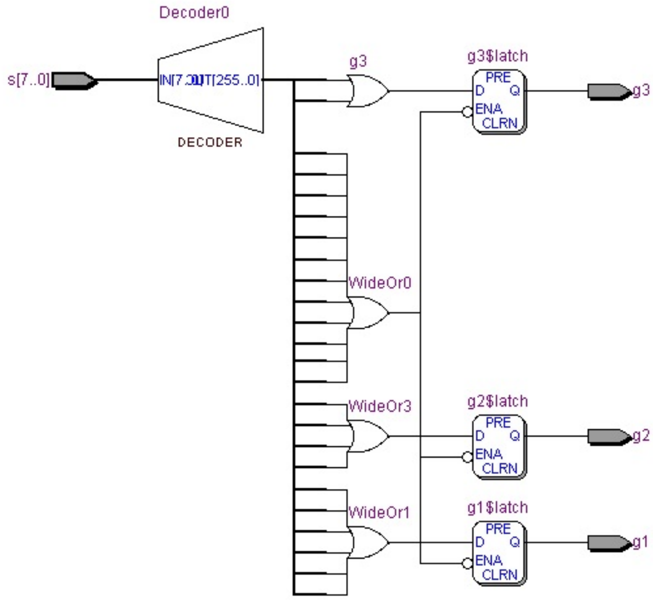


Fig. 8. RTL Diagram.

## V. Results

Figure 9 show the wave output of power management algorithm in ModelSim. Wave output clearly show, how thermal generation units become operational by taken the decision of algorithm depends on the input of solar generation unit. Waveform also show that solar generation unit give eight bit input to the algorithm on the basis of power deficiency. In return algorithm generate a single bit signal to trigger the single thermal generation unit operational. All of signal input to the algorithm and output from the FPGA based algorithm unit is received and send to the switching circuit units. The switching circuit unit is responsible to operate the thermal generation units.

## VI. Conclusion

The smart grid is largely depends state of the art technologies. For example, information related to each generation unit, to distribution unit, and from distribution unit to load needs information system [2] and energy management system [3], [14]. In future all automobile will also use electricity to reduce carbon emission[4], [11]. It is necessary to divert all of out dependencies to renewable resources. This algorithm will help to manage the power utilization and control in smart grid environment. It is also evolutionary less complex and by the increment of generation unit it's complexity will also increase linearly as show in equation 2, 3, and 4.

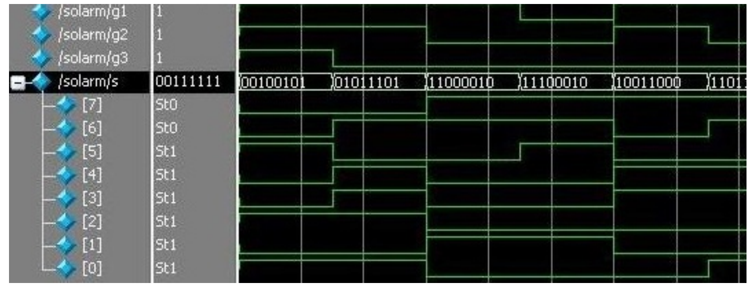


Fig. 9. Output Waveforms.

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