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A PLD POWER BACKUP CONTROLLER MODEL FOR A SOLAR POWERED TELEMETRY SYSTEM

Ishmael Zibani[1], Mandu Jeffrey[2], Kelebaone Tsaamase[3], Edwin Matlotse[4], Ibo Ngebani[5]
[1-5](Electrical Department, University of Botswana, Botswana.
zibani@ub.ac.bw

ABSTRACT : *In this investigation, we are demonstrating a control system for a solar operated, remotely controlled telemetry system, which is backed up by a diesel generator. The telemetry system is normally operated using a solar system. However, if weather conditions are not favorable, e.g., prolonged cloudy days, the solar system may not have enough power to operate the telemetry. In such a situation, the controller switches over to the diesel generator before the solar backup batteries run out. The system also monitors the generator oil and fuel levels at all times, and gives a warning signal for an engineer to visit the site to fix this. The controller was implemented on an EPM7128SLC84 CPLD Altera Device. The simulation and hardware testing were successful. The controller was implemented on a programmable device for ease of design reconfiguration, should the need arise.*

KEYWORDS *– controller, generator, reconfiguration, solar, telemetry.*

I. INTRODUCTION

The Remote telemetry systems are widely used in water resource management, environmental monitoring, oil and gas pipelines, and communication infrastructure [1, 3, 6]. They are often deployed in remote or hard to reach locations, with no or unreliable power grid. In such situations, autonomous, renewable energy, such as solar, is used to power the system. Solar is considered efficient and sustainable powering system suitable for a remote telemetry. The solar system normally includes an array of solar panels, a charge controller and a battery bank. The solar panels produce electricity during the day to power the telemetry system with excess power used to charge up the batteries for later use when the panels no longer receive sunlight at night. Furthermore, increased cloudiness or rain can drastically reduce the energy generated by solar, ultimately leading to a catastrophic failure of the telemetry system [8,9].

Usually, a remote telemetry will incorporate a backup system, like a diesel generator which can be operated remotely. Real-time information on operational status, fuel levels, temperature, oil pressure, and more can be relayed to the control center via GSM Communication modules or similar.

This study introduces the use of a programmable logic device, instead of the usual serial instruction execution seen with microcontroller implementations. The design approach used here, can be used to motivate students appreciate parallel design approach and the advantage of (on-the-fly) reconfiguration. For academic institutions, ALTERA provides free Quartus II softwares and development boards [10, 11, 12].

II. TELEMETRY MODEL

The model for the proposed system is depicted by a function diagram of Figure 1. It consists of an array of solar panels, Intelligent Battery Charger and Power Distributer (IBC&PD), solar batteries, inverter, power supply selector (PSS) device, diesel generator system, control unit and the load. The control unit coordinates activities of the telemetry system [2, 4, 7].

Power backup controller constantly checks the operating conditions, the solar charge battery level, and generator health. Priority is given to the solar panels to supply power since its free energy. If solar panel can't supply enough power and battery drops below a safe level, the controller starts the generator via a starter motor and then transfers the load from the solar supply to the generator supply, after confirmation that the generator is in good operating condition. This involves checking oil levels and fuel levels [5].

On a normal shiny day, the solar array will have enough power to drive the telemetry load and also charge up the solar battery. The IBC&PD charges up the solar battery and also decides whether to use battery power or solar power. The telemetry load is normally driven by the solar power, unless if it's not enough (as during a cloudy day or at night), in which case, the load is driven by the solar battery via the inverter [13, 14].

During prolonged cloudy/rainy days, the solar system may not have enough power, in which case, the controller will select the diesel generator (through the PSS) to supply power to the load. The health of the generator system (oil, fuel and it's start up battery) is continuously monitored. A fault reporting will be send to the control room if any of the monitored components become faulty or malfunctions.

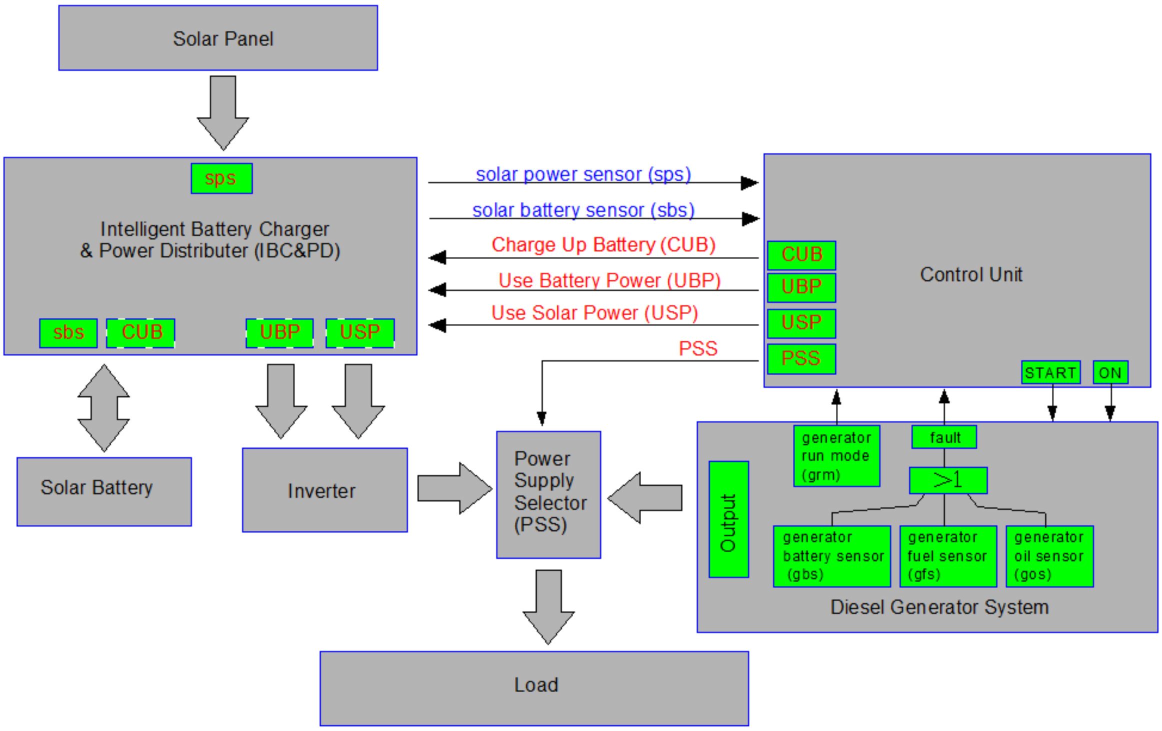

Figure 1. Telemetry Function Diagram

III. FINITE STATE MACHINE (FSM)

Figure 2 shows the Finite State Machine (FSM) of the control unit. It is at the heart of the telemetry system [15]. The control system receives signals from the data section of the telemetry system. It then responds by sending out commands (outputs). The control unit has 4 states, which are discussed below.

PANEL state.
Input Conditions:
>sps.(fault)¯-when the solar panels have enough power and no generator fault (ideal condition)
>sps.fault/REPORT-when also there is a generator fault, which is reported, together with normal solar operation.
>(sps)¯-when solar power is not enough to supply the load, we go to state BATTERY.

BATTERY state.
Input Conditions:
>(sps)¯.sbs.fault/UBP,REPORT-solar panel can't supply, but solar battery can (UBP=1), with generator fault reported. We remain in BATTERY state.
>(sps)¯.(sbs)¯.fault/REPORT-when panel and solar battery are exhausted, and there is a generator fault, the fault is reported and we stay in the BATTERY state.
>(sps)¯.sbs.(fault)¯/UBP-solar panel can't supply, but solar battery can (UBP=1), with no generator fault. We remain in BATTERY state.
>(sps)¯.(sbs)¯.(fault)¯-when panel and solar battery are exhausted, and there is no generator fault, we go to RUN state, to try the diesel generator.
>sps/UBP when panel power becomes available, we go to PANEL state (with UBP=1, still.).

RUN state.
Input Conditions:
>fault – when we encounter a generator fault, we just go back to BATTERY state.
>(fault)¯.(grm)¯-in the absence of a generator fault, the diesel generator is turned on and started up.
>(fault)¯.grm-with no fault, when the generator reaches optimum speed, it enters the run mode, and we go to GENERATOR state so that the generator start driving the load.

GENERATOR mode.
Input Conditions (16)
>(sps)¯.(sbs)¯.(fault)¯.grm (1)-panel and solar battery are exhausted, and in the absence of a generator fault, and the correct generator rpm, and PSS=1, the generator will be supplying, and keep running as long as ON=1.
>(sps)¯.(sbs)¯.(fault)¯.(grm)¯(1)-unlikely condition, however, next state is the PANEL state.
>(sps)¯.(sbs)¯.fault (2)-panel & solar battery out, with generator fault, go straight to PANEL state.
>sps (8) – solar panel is on, go straight to PANEL state.
>(sps)¯.sbs-solar panel not ready to supply, but solar battery is ready, go to BATTERY state.

Note that the generator fault can be tolerated while using the solar system; the fault signal (*REPORT*) is generated and communicated during this time. However, the generator cannot operate while it is faulty.

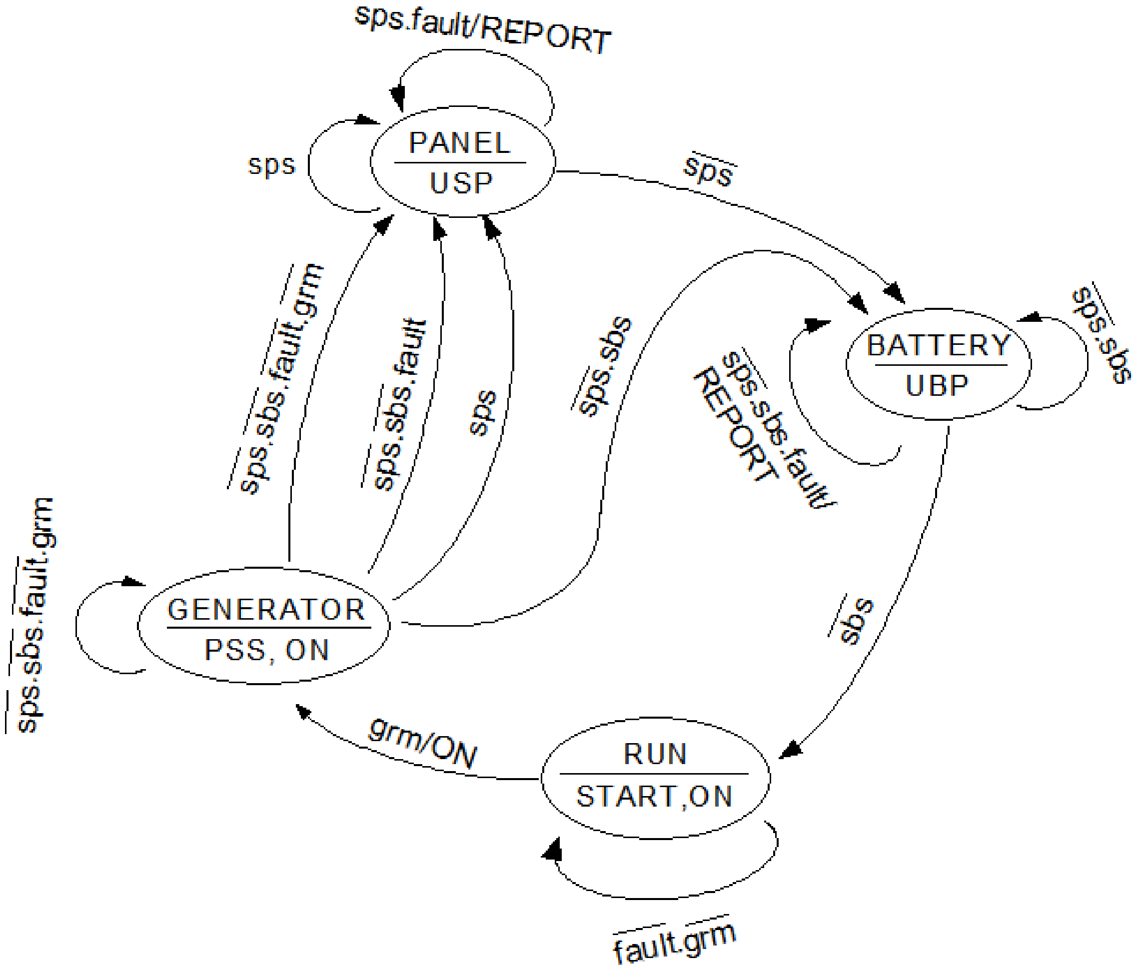

Figure 2. Finite State Machine (FSM) representation of the Control Unit.

IV. CONTROL UNIT IMPLEMENTATION USING ONE-HOT_STATE_ASSIGNMENT

The logic diagram of figure 3 is One-Hot_State_Assignment (OHSA) implementation of the Control Unit, []. In the OHSA implementation, each state in the FSM is represented by a flip-flop. State transition decisions are represented by demultiplexers. Moore outputs stem out of flip-flop outputs whilst Mearly outputs stem from outputs of de-multiplexers []. Circuit initialization involves presetting the first flip-flop and resetting the rest. The first state is considered the default state. State transitions are symbolized by the movement of the logic 1 value from the original flip-flop (state) to the rest of them, guided by the selected outputs of the de-multiplers. The inputs determine which de multiplexer output path is selected. The advantage of using OHSA is direct implementation, without using state tables and k maps. The circuit can easily be built and simulated on Quartus II [15, 16.

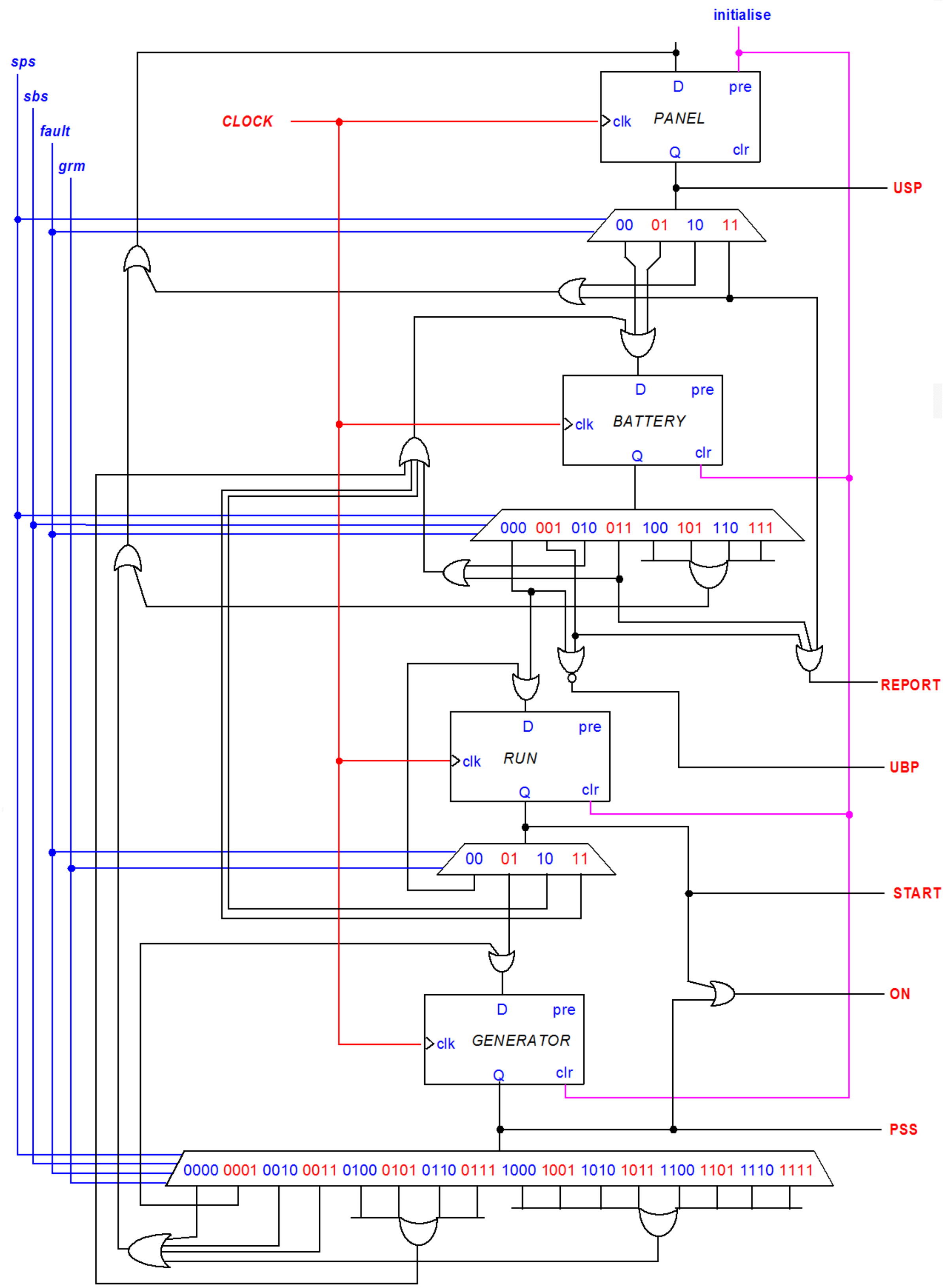

Figure 3. One-Hot-State-Assignment of the Control Unit

V. ALTERA'S QUARTUS II SIMULATIONS RESULTS AND DISCUSSIONS

Quartus II is a powerful hardware simulation and implementation software from Altera [15]. It accepts different inputs; schematic, code, waveform, etc. Quartus project designs can be implemented on programmable logic devices (PLDs). Unlike microcontrollers, PLDs are reconfigurable and allows parallel execution of instructions [17]. For this project, EPM7128SLC84 CPLD has been used.

The design of the control unit involves 4 states and 4 inputs, therefore each state will have 16 input transitions to look at. A total of 4 states translates to 64 input transitions. To avoid loss of generality, we have simulated one of the most likely transition strings, and it is discussed here. The string is described by certain input conditions as we transit from one state to the next. Figure 4 shows the chosen string which was used to test and verify the functionality of the control unit, using max plus II simulation waveform editor.

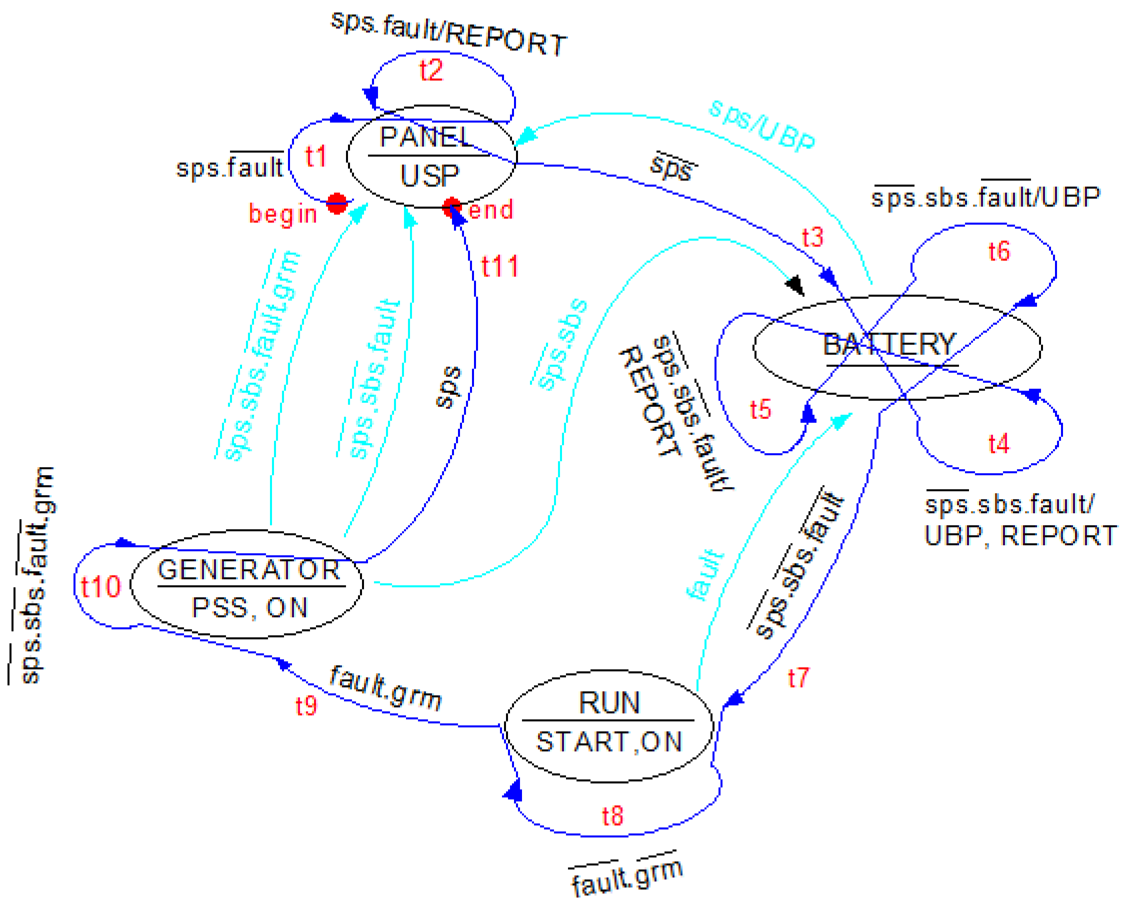

Figure 4. Test String used in the simulation.

The simulation results are shown in figure 5. Note that inputs not relevant to a particular state will appear as don't care when that state is in consideration. The input/output are listed on the left of the waveform. For ease of reference, the abbreviations are indicated here as follows.

Inputs:
solar power sensor – sps
solar battery sensor – sbs
generator run mode – grm
fuel, oil, battery sensor – fault
Outputs:
Use Solar Power – USP
Use Battery Power – UBP
Power Supply Selector – PSS
START
ON

REPORT

The waveform string starts at t1 with sps=1, fault=0, resulting with the FSM remaining in state PANEL, and the solar panel supplying power (USP=1).

At t2, sps=fsult=1, there is a generator fault reported (REPORT=1), and panel continue supplying power (USP=1).

At t3, sps=0, we transit to state BATTERY, to check is solar battery has power to supply.

At t4, sps=0, sbs=fault=1, solar can't supply, solar battery is supplying (UBP=1), and generator fault is reported (REPORT=1). We also remain in the BATTERY state.

At t5, sbs=sps=0, fault=1. Solar panel, solar battery or generator can't supply. We remain in BATTERY state and report generator fault (REPORT=1).

At t6, sps=fault=0, sbs=1. With no fault, solar battery continue to supply power while we remain in BATTERY state.

At t7, sps=sbs=fault. With solar system out, and no generator fault, we proceed to RUN state.

At t8, we are in RUN state, with fault=grm=0. The generator is put on and started (ON=START=1). Since the generator speed is still lower than the idle speed, we remain in the RUN state.

At t9, fault=0, grm=1. Generator speed has reached idle speed, and we proceed to the GENERATOR state.

At t10, sps=sbs=fault=0, grm=1. With no generator fault, generator speed at idle (grm=1), the generator will continue to supply power (PSS=ON=1). We remain in GENERATOR state.

At t11, the solar panel is up (sps=1) and its able to supply power. So our next state is PANEL.

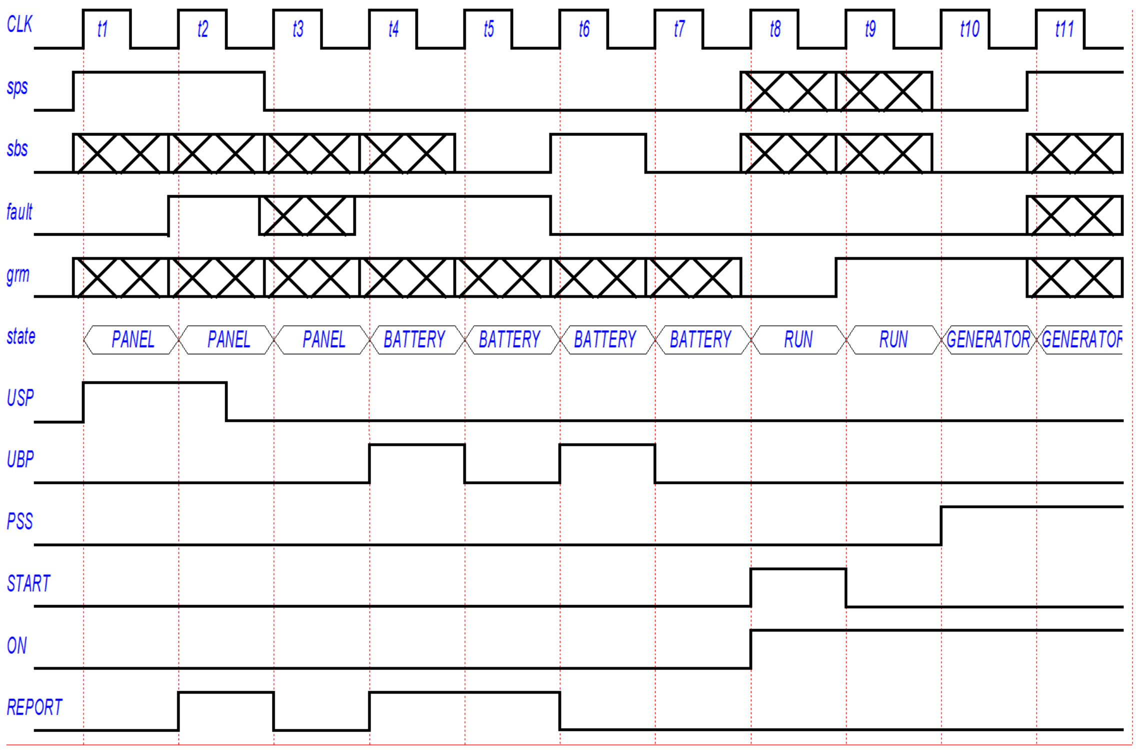

Figure 5. Input/Output Waveform for the Control System

VI. DEVICE PROGRAMMING

The Quartus II software contains a programmer, which was used to program the EPM7128SLC84 PLD device. The USB blaster provided the necessary interface between the PC and the Altera Development Board used. The control unit design was successfully programmed into the chosen PLD and tested using the I/O terminals on the board [17].

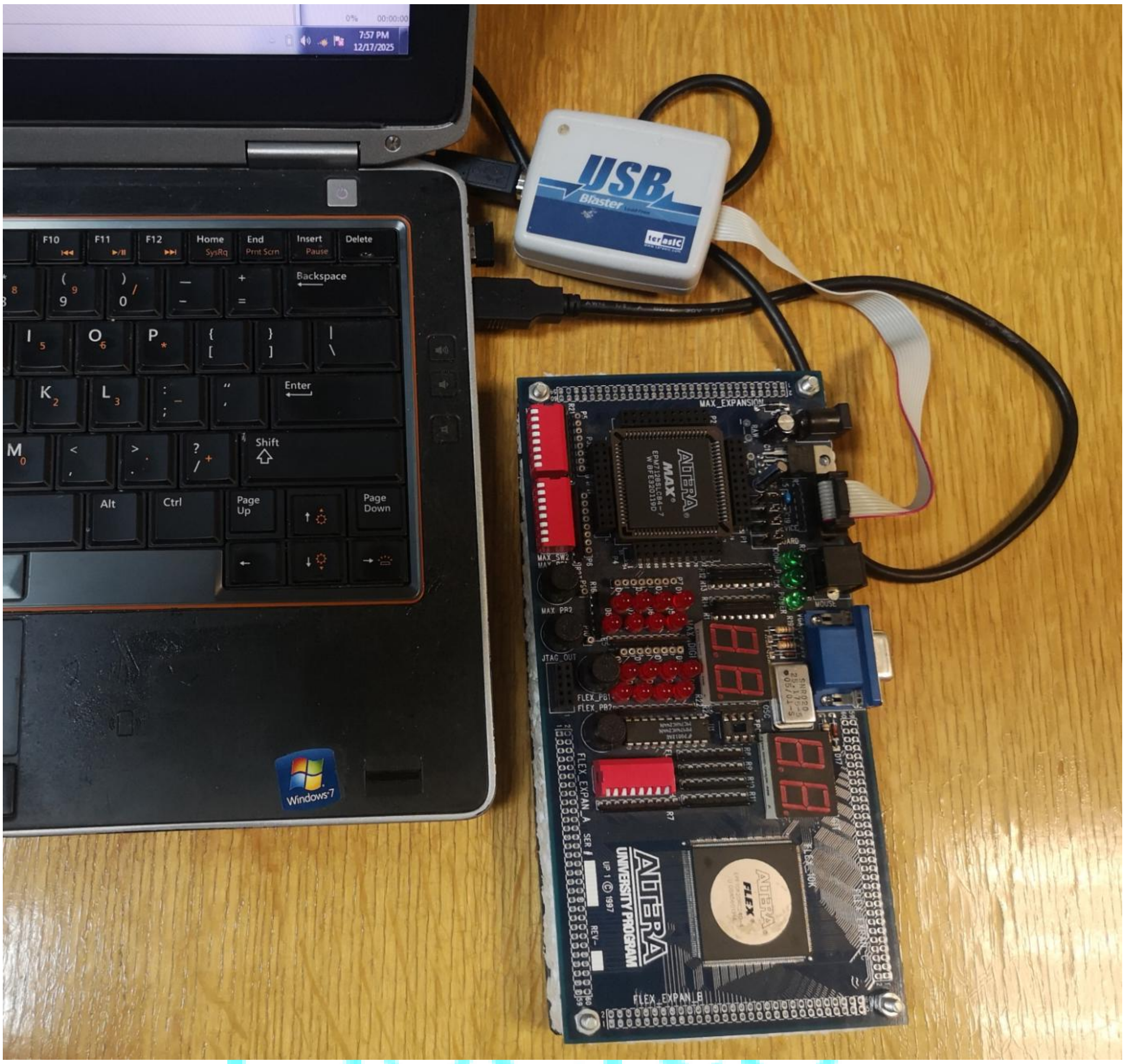

Figure 6. ALTERA *EPM7128SLC84 Device Programming*

VII. CONCLUSION

The successful simulation of the telemetry control unit demonstrated the advantage of using a reconfigurable programmable device. The design of the control system can always be modified and the modifications can be programmed remotely. A repair engineer can go to the site only to attend generator faults. Furthermore, this project demonstrated the one-hot-state-assignment implementation on a PLD. This is a useful design technique which student can find useful when designing digital systems.

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