DEVELOPMENT OF DIGITAL AUTOMATION SYSTEM FOR THE UTP INTEGRATED RENEWABLE ENERGY POWER GENERATION

by

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Supervised by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical and Electronic Engineering Programme
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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

APRIL, 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgment, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD HAZIQ BIN MOHD YUNUS

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Abbreviations and Nomenclatures

RE	Renewable Energy
Mmmt	Million Metric Tons
CO_2	Carbon Dioxide
PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition
EU	Energy User
HMI	Human-Machine Interface
IRES	Integrated Renewable Energy System
RIO	Re Configurable I/O
RT	Real-Time
FPGA	Field Programmable Gate Array
UUT	Unit Under Test
RTOS	Real Time Operating System
VI	Virtual Instrument
MXP	myRIO eXpansion Port
MSP	Mini System Port
AI	Analog Input
DI	Digital Input
AO	Analog Output
DO	Digital Output

Abstract

Renewable Energy (RE) got advantages over the conventional fuel energy generation. The only obstacle emerge is the supportability to the load demand and intermittency of power. This problem makes the natural resources are wasted for many years. Many approached had been applied from previous study. However, it required a high cost to develop the system. Home or commercial sector cannot afford to invest in implementing this technology. In conjunction of increasing the efficiency of power extraction, the centralized system are yet to be developed. The innovation of low cost system are still available to challenge. In this study, an approached proposed is to use the board from the National Instrument myRIO-1900 Reconfigurable I/O (RIO) and LabView software for commercially approach. By implementing this board and software, the integrated system of many sources from renewable energy are expected to develop. The approach that the study will proceed is the Hybrid-coupled technique. The network will consist of Solar Panel, Wind Turbine and Wave Energy Extractor as the main natural resources. The system also will be able to monitor and control the input and output of the sources. The configuration of the system will take into consideration of economic, potential of energy and safety. Successful development of this project, will result the integrated renewable energy system is centralized with the desired configuration using the proposed method.

ACKNOWLEDGEMENT

Alhamdulillah, praise to Allah S.W.T. for His non-stop guidance to me through my life. Grateful to Him, without His Guidance, succeed will not followed even in this study.

I would like to say thank to my Final Year Project Supervisor, AP Ir. Dr. Nursyarizal Bin Mohd Nor, for his continuous support. Besides, his patience, knowledge sharing and verbally and written motivate me to proceed to the end of this study.

Not to forget for Universiti Teknologi PETRONAS (UTP), for giving me opportunity for me to be here, through my undergraduate life especially for this particular course. This course had taught me to be come more engineered thinking than my previous year and prepared me for the real situation at out world.

Indeed, I would like to thank to the industrial people who did help me in completion for this project. From my previous internship's company, Emerson Process Management staff who did taught me a lot about the industrial control system in basic and advanced usage of it. Also, from National Instrument's engineers, that providing a support for the development board, NI myRIO 1900 and their training module.

For the most part, I should thank to my parent and family for their support through this adventure life. Of course, without them I might not be here, proceeding this study and this project to the end until succeed.

Chapter 1
Introduction

1.1 Background

Electricity is one of the essential to human daily life. Since we are in the period of modernization, everything is digital which is required electricity. Demand about electricity never get to stable amount, instead, it is increasing more and more. This is pushed many power provider to put all their machine in running to satisfied the demand. The real concern is the product that power provider release from the prime mover.

Since majority of the world are using the fossil fuel prime mover, the emission of carbon dioxide to the air is in big concern. The increase of earth's temperature is one of the problem. Fortunately, the existent of RE in our daily life making sure that we preserve the earth peacefulness.

The ideas to put solar energy extraction in every single roof is one of the good initiative. This more or less, helps in reducing the demand, leads to reduce the carbon emission. The other may thinks to totally put trust to the RE itself which is the best idea in and can almost eliminate the carbon emission in power generation sector.

The development of the RE are the concern. This is because the problem that user will face made the solution to have many sources of RE in one particular network. The ideas and design had been proposed about integrating RE into one system. Hence, the demand can be occupy whenever needed.

Stand-alone RE system are yet to be developed in UTP. The sources of the energy is from the wind turbine, solar arrays and wave energy. The integration of this energy need a consideration of the economics and ability of the sources to supply the demand at the first place.

1.2 Problem Statement

In the development of the system, there are some constraints that need to get into consideration. These constraints and challenges are as follows:

a. Integration of power is needed between various of the sources.

b. System of monitoring and controlling capability is needed.

c. Configuration of the system needs to have consideration of economics and the source(s) ability.

d. A backup sources need to be working when the power loss or power fluctuate.

e. Human-Machine Interface need to be developed.

1.3 Objectives and Scope of Study

1.3.1 Objective

1. To develop the integrated renewable energy automated system of solar panel, wind turbines and wave energy.
2. To develop system that be able of monitoring and controlling.

1.3.2 Scope of Study

In the study of developing the monitoring and controlling system for the IRES, the limitation of the development is the cost. The consideration of this cost take into two part which is the cost of the system and the management of the operation of source(s). The cost in building the system also consider to the less investment involve.

The IRES development will also only consider the energy management and the decision of which of the sources will take the first place of the supplying the power. The factor of controlling the quality of the power produce is not within this study. Due to this, the system will ensure that the source(s) which is available is the source(s) that provides the standard power rated.

Chapter 2
Literature Review

2.1 Previous Study Review

The concern about the carbon emission has raise awareness among the human about the only human-can-live planet, the Earth. World are depends on the electricity generated from the fossil fuel generation plant. Currently, the only plant that capable in providing the electricity is the fossil fuel power generation. The power generation plant using the fossil fuel had proof that the electrical energy extracted 60 % of efficiency on their own[1]. This made this famous solution to almost impossible to be vanished as the primary power generation.

A. Environmental Quality

Research and survey had show that the emission of pollutant from this plant contribute big percentage of the environmental pollution especially to air quality[2]. Reported in [2] that the CO_2 emission by the commercial sector due to usage of the electricity increase by 13 Mmmt during 2013. The demand of electricity made the generation plant pushed to use more fossil fuel to move their generator. In conjunction to the increase of prices of natural gas, the power plant that use this fuel basis had decrease by 10% in 2013[2]. In spite, coal generation plant rise about 4.8% in 2013.

The only way to reduce the usage of material that in the end will produce bad consequences is to change it in the usage of RE Resources. Instead of avoiding the high prices of resources especially fossil fuel in power generation, the natural resources is replacing the position. This is proven when report was written by [3] about the increase of renewable electricity generation. The vast number grows of RE generation is solar energy which recorded 1.9% increment. Efficiency of electricity generation to the operation is high. The importance in the usage of the RE made the economical aspect reduced. In recent years, many natural resources had showed the capability in generate electricity. In such is wind turbines, biomass, tidal, wave and commonly known is solar photo-voltaic. Unfortunately, the RE generation itself cannot sustain the electricity demand of the world population and industrial sector.

B. Renewable Energy Advantage and Weaknesses

Intermittency of the power being generated is one of the problem[4-5]. The advanced technique are proposed in [5], where industrial solution is introduced. The usage of the PLC in the wind energy extraction by having fuzzy logic controller can increase the efficiency of the energy being extracted. This need configuration in combination of wind speed and different loading conditions.

Scheduling in overcoming the intermittent need supply and demand management[6-7]. By doing so more energy can fully be generated and used. But this management technique required forecasting. In advanced findings, the calculation of the probability of the event in done[7]. By using the data and information of the power reliability which correspond to the number of solar panel arrays, wind turbines and the rated capacity of the energy storage, the technique of stochastic calculus is made. This technique made the prediction of energy generated possible.

Sometimes, in low demand mode, the power extraction may be high. The consideration of presenting energy storage is important, so that, the energy is stored for later use[5,8]. Especially, during the peak load where the power extraction is not enough to support the load demand. The usage of the energy storage or battery can reduce the tension face by the generation site. It is much more alike the function of capacitor bank but it's improved the period of operation. The rating of the power input of energy storage is DC. If the input is AC, then the conversion of power is needed.

C. Control System of Renewable Energy

It is proven that the scheduling of RE is important. Then if the sources of energy is more than one, means the sources must introduce the dominant in providing direct power to the load and the energy storage charging sources. In a very later application, a continuous operation may not required man to changing the element of power sources. An automation system is introduced[9,4,10-11]. The automation system implemented can be SCADA, PLC or any automation system that capable in maintaining the network.

Monitoring the system and giving an output command to change the element that crucial to control must be present into the network. In the present of the system, many consideration need to mull over for the system to be properly configured. One of the consideration is the economical factor and theirs potentiality. In [6], the economical factor is associate with the demand by the implementation of two-way communication between the consumer and the generation site. This is by using the smart meter given to the Energy User or EU. EU will tell the generation's operator that they need demand in electricity by given time, date and period. This means the forecasting of the energy demand can be more easier. By logically, the potential sources of energy for the demand can be determine and the other sources of energy can be shut off to reduces the operating cost.

Monitoring also will determine the source(s) of energy which then will tell the system to switch the feeder for supplying to the load. Conversion of power made the possibilities of having a good quality of power produce possible[12]. By combining the power conversion and integrated monitoring and control system quality power could be control. This ensure that the power quality in term of stability of the voltage, frequency, balanced power and non harmonic power supplied[4].

D. Geographical Opportunity

In Malaysia, where the place of this research and finding are done, the RE that takes into consideration is utilizing the geographical factor of this country. Near to the equator of the earth made Malaysia as the higher potential to solar energy generation.

The tropical factor of the geography made the wind energy extraction possible. Report had been studied about the possibilities of the wave generation and the possibility is there, in the east part of Malaysia[13]. Later, the discussion about the integration of RE which will take into consideration of solar panel arrays, wind turbines and wave turbines will be conducted.

2.2 Description of the Literature Review

More details about each of the past literature that had been review are elaborated belows. It is the summary, advantages of the studies and the problem arise from the past research works.

2.2.1 Renewable Energy as Side Generation

Furukawa K., Katoh D. and Onishi T. (2012), discuss that in improving the power demand at the load side, Distibution Generation or DG is installed, typically at the distribution area. However, in many cases, the power quality is affected. In the future, the system is developed to control about is disturbing factor to the distribution network. This paper suggesting the next generation of the SCADA system using Hitachi technologies. In this paper also, they are discussing about the emerging of a new technology that is called Static Synchronous Generator / STATCOM and Power Conditioning System / PCS. They are also considered the chance of sources of energy from the Electric Vehicles or EV. For the system, any information is passed through the Enterprise Asset Management (EAM) Server which will then being process.

Maza-Ortega, J. et al. (2012), investigates that instead of having a type of generator for occupy the need of the grid demand, this paper discuss about occupying it with the usage of any DC bus/link to the network that does not require any automation system. This is by boosting and converting the DC to the voltage rated in AC. It can be perform by applying VSC from the DG. The reaction of the VSC might be quick enough but problem arise when there is only a voltage sag for a temporary of time. This is because once the network is in stable the VSC will auto-re-close that may cause the voltage sag again and triggering the other VSC.

2.2.2 Techniques in Controlling Renewable Energy

Wang K. et al. (2012), developed a forecasting technique are done using a stochastic calculus. The factor to consider is loss of power supply probability, fraction of time that energy is not-served and waste of power supply. This lead to the needs of energy storage for the energy extraction from the Solar PV and wind turbines. This is to prevent the wasted energy being drawn off as losses. The concern about this implementation is the duration of the battery or energy storage to supply power during the energy not extracted from the sources.

Wu, Y. et al. (2014), proposed technique in scheduling the energy sources to provide sufficient energy on demand which involved the centralized source. The technique approach by the authors is by having a group of energy user (EU) who are equipped with smart meter. The information from the smart meter will tell the center of RE to optimize the energy usage from the grid or / and RE. The real concern here is the sources of the energy does not rely all the sources from the RE.

Wang, L. and Liu, K.-H. (2007), implement the control system by configuring the system using fuzzy controller. The system are defined as centralized control system for the hybrid integration between the Wind and PV as primary source of energy. The controller as use as the configuration of the effective energy management for distributing the power to the load. Due to the technology usage which is the industrial controller, the implementation might be very expensive to be applied commercially.

Yang Fan et al. (2012), investigates the usage of the RE to replace the diesel generator after considering that the operational of the RE sources is more applicable at where the place or demand suit to its capability. The amount of the power that can be supplied is 23MWh/day. For this reason the network does not require a system and replace with the Bi-directional Inverter that is useful in maintaining optimum power quality and managing flow of energy.

2.2.3 Synchronization or Integration Method

Kabalci, E. and Gorgun, A. and Kabalci, Y. (2013), proposed that the integrated sources of the RE can be a form of three approach. The three of them is AC-coupled, DC-coupled or Hybrid-coupled. The approach are best according to their application. The monitoring system that is developed are based on the commercial use of the micro-controller. Coded using Visual C# makes the monitoring control are more capable in storing the historical data. The monitoring system are build with less cost due to only use the commercial micro-controller. The system are build only for the purpose of monitoring the voltage and current.

Bhoyar, R.R. and Bharatkar, S.S. (2013), proposed design for rural state in India that are not connected to their gird system. They proposed to implement many types of sources of energy to be distributed to residential usage. The paper also claim to put the RE into backup sources once the grid network facing faults in a transient period. Instead of claiming the benefit's of RE such as to lower the carbon emission, the paper also advancing his idea to put Electric-Vehicles into the sources of RE. The real concern is how the RE can provide sufficient power at any instantaneous period during the event at the grid.

Hyun-jae Yoo et al. (2009), implement a system that have measurement of voltage and current. Any sources of power systems that are integrated to each other need a system in order to make the systems works fined. If there are no controls elements exist, the power systems have a big chance to the fault problem. Such of the problem is voltage dip or sag or reverse power flow. Unfortunately, the control system that can offer the capability to reduce this fault occurrence is too expensive to invest for small scale generation site. This can be more cost effective if we can build it with low cost. Some design is applicable to be implemented for these purposes but in high cost. If we are able to invent the system by ourself, we also need to ensure that the system have same capability and integrity as the industrial approach.

Delimustafic, D. et al. (2011), proposed design on how to optimize the usage of power in the development of Hybrid RE System (HRES). The implementation will be use the power converter such as DC-DC Buck Converter and AC-DC Inverter. The power come in and out alternately. There was only one input and output. The advancement can be made from this paper which we could have more input for the energy storage charging purposes.

2.2.4 Backup Systems

Zadeh et al. (2011), discuss about the integrated system from many RE sources. The RE is suitable in maintaining a small area or to feed small communities. When the RE is provided with monitoring system, the power generated can be very useful and also efficient. Some criteria in building the system are discussed in the paper. They also implement a system that use the hydrogen storage tank to power up electric vehicles.

Xiangjun Li et al. (2012), suggest that in consideration of using sources of power from intermittent sources, a backup storage is needed. This can cover up if the sources fail in sudden and the power can be extract from the energy storage. Large scale of Lithium-Ion battery is use for this application. Makes the generation plant capable in providing power as the conventional plant already exist. Cost and economics is important in our consideration. Large battery is equivalent to huge investment cost.

2.2.5 Newly Emerge Renewable Energy

Jaswar et al. (2014), investigates that the opportunity of the extracting energy from wave in Malaysia is possible. The Wave energy are proposed to be extracted in Malaysia at the South-China Sea located at Marang, Terengganu. This is the suitable location for the wave extraction due to the wave condition that is harsh than other places in Peninsular Malaysia. The generator or device to extract the power able to functioning even in 0.5 meter of wave-which is the typical height of wave in Malaysia. Unfortunately, the capability of this wave generator are debated due to its highly capital cost and the operational period. In Malaysia, the wave generation can only operated only for the half of the year which the wave is suitable for the wave energy extraction.

Chapter 3
Methodology / Project Work

3.1 Methodology

The required system in the Integrated Renewable Energy System (IRES) is to maintain a stable distribution of power. In order to develop the system, a list of task is required. Further, in this report, which within current chapter includes a gantt chart of the task schedule, procedure, tools and equipment use and the expected outcome for the system. More elaboration about the details of the subject is defined.

In short, the development of the IRES are divided into two phases. At the first place is the Design phase and the second is the Implementation phase. The flow diagram of both phase is clearly illustrate in Figure 3.1 and Figure 3.2.

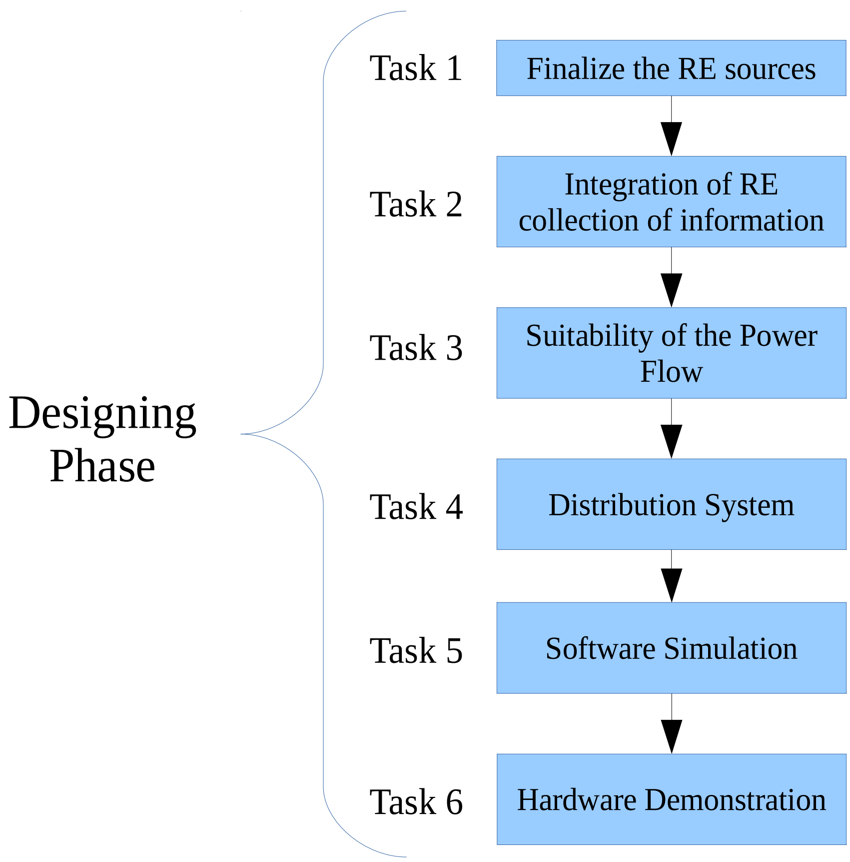

Figure 3.1 : Details of the Designing Phase.

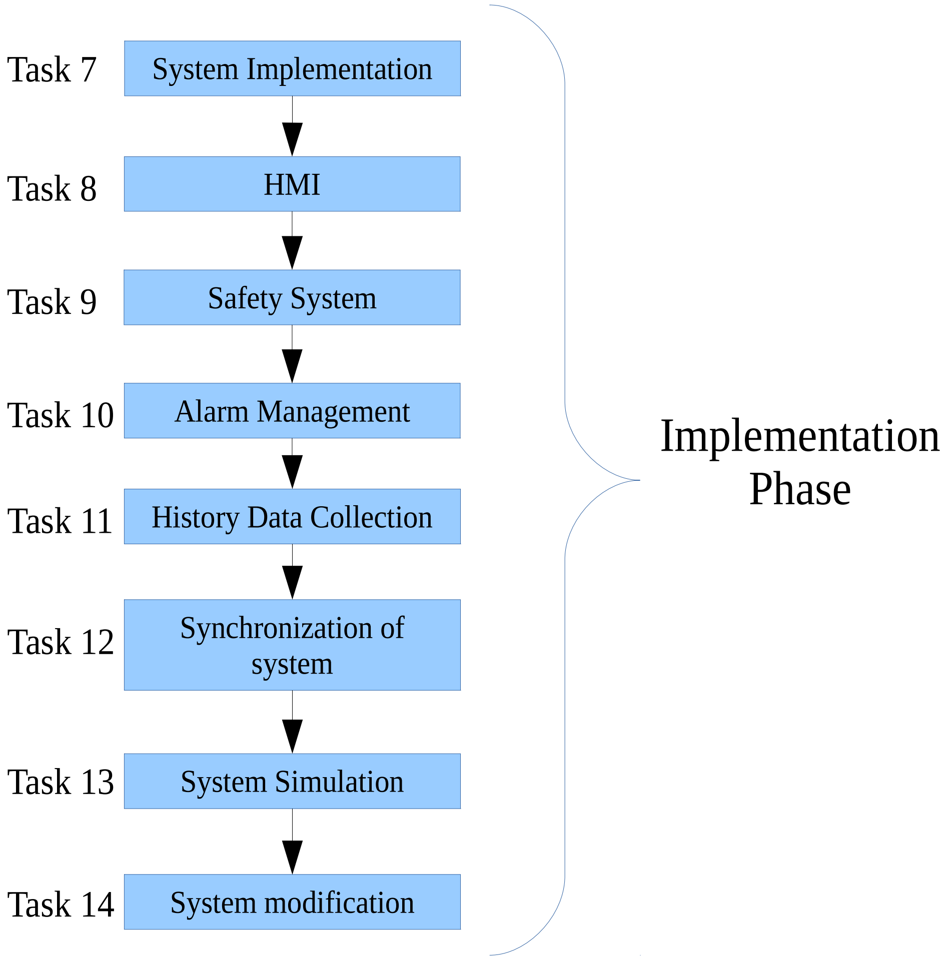

Figure 3.2 : Details about the Implementation Phase.

3.2 Procedure

Developing the integrated RE required steps that need accomplishment of task accordingly as shown in Figure 3.1 and 3.2. The sources of RE are from the solar panel arrays, wind turbine and wave power (Task 1 of Figure 3.1). To implement this three RE power into the network and all the sources have to be integrated or aggregated at the first place. The network is said to be stand-alone system. This means that the system is existed to ensure that the power is regularly distributed to the load. In integration of power, any amount of the power extracted is use wisely. In order to satisfied the load needed, backup equipment are ready to takeover the task in the case(s) of power instability(Task 2,3 of Figure 3.1).

The mechanism proposed for solving the intermittency issue(s) is by alternating the sources by the factor of potentiality or ability to the rated load and the economical aspect in operation of the power sources(Task 4 of Figure 3.1). In an energy management, scheduling is the best options. This is by the helps of the backup device that available in the network. Backup device is energy storage or a battery and in the worst scenario diesel generator.

The system that going to be develop need to have the capability of monitoring the network, instead of having a control over the feeder to react to the changes in the power generated(Task 5,6 of Figure 3.1). In some situation, the power may be use as the main supply to demand or if the potential is not enough than the rated demand, the source will be directed to charge the energy storage.

In the implementation phase, more details configuration are needed. Throughout the task of 7 until 11 of Figure 3.2 is shown. These configurations are required as it is a must in any industrial solution. When more details and configuration are in the system, the system can work almost fully automated. Once the software and hardware are done, then, the synchronization between both two are needed(Task 12 of Figure 3.2).

Before the system can be commissioning, the simulation take place to verify overall operation of the system. If the configuration is unsatisfied, then, modification have to be made(Task 13,14 of Figure 3.2).

Results of each task in each phase are shown in next section throughout the report.

3.3 Gantt Chart

As per schedule, the gantt chart is prepare to ensure the progress of developing the integration of RE succeed. Appendix 1 is useful for the Gantt chart details of the project.

3.4 Tools and Equipment

The system proposed is based on system of SCADA. SCADA system are expected to their capability in monitoring and controlling the configuration of the system as according to the potentiality and economical aspect.

In conjunction to this, NI myRIO 1900 is use to implement this design in small scale to proof the working of the configuration. More details explanation about the usage of the board is discuss throughout the report, which is in the next two section.

3.5 Economical Aspect of the design approached

The design of the system are expected to include consideration of economics and ability of the sources. For the first configuration of economic, the RE will be rank to the low of the operating cost to be at the first place. This will ensure that the power extraction will be balance with the operation of the sources. The rank are expected to be solar panel arrays as the prior in power provider. To the next priority is the wind turbines follow with the wave energy.

Due to the availability of the source, it is possible that all the RE cannot provides the power to the load. Hence, backup power is introduced. This backup are involves the battery and diesel generator. Battery is at the higher priority than diesel generator. This suits to our objective to reduce economical factor. The usage of the diesel generator only when all the low cost power provider cannot functioning well or required maintenance or battery's have to low power quality.

The battery need to be discharge regularly. This is because to maintain the quality and the lifetime of the battery, it has to be use regularly without neglecting that the power needs to be available in standby mode. Hence, the power to be supply at the load will be use as the direct supply and the other source(s) that available will be use as power charging of the battery. By implement this step, the system are expected to be stable and will be able to supply power at the case of power down and give enough time for the operator to get ready to provide more power if it is needed.

In addition, monitoring and control interface that are needed make the operator easy to implement their action. The progress of the interface of particularly call as Human-Machine Interface is illustrated in the Appendix 2 of this document. Clearly shown inside the illustrations is the power flow and the current value of the system. From this HMI, the operator can see the current conditions within the network. Further, this HMI will be updated so that the operator will be prompt with alarm and any event occur will be stored in the historical list that help the operator to analyze the situation of any days within the historical data.

3.6 Flow of Operation

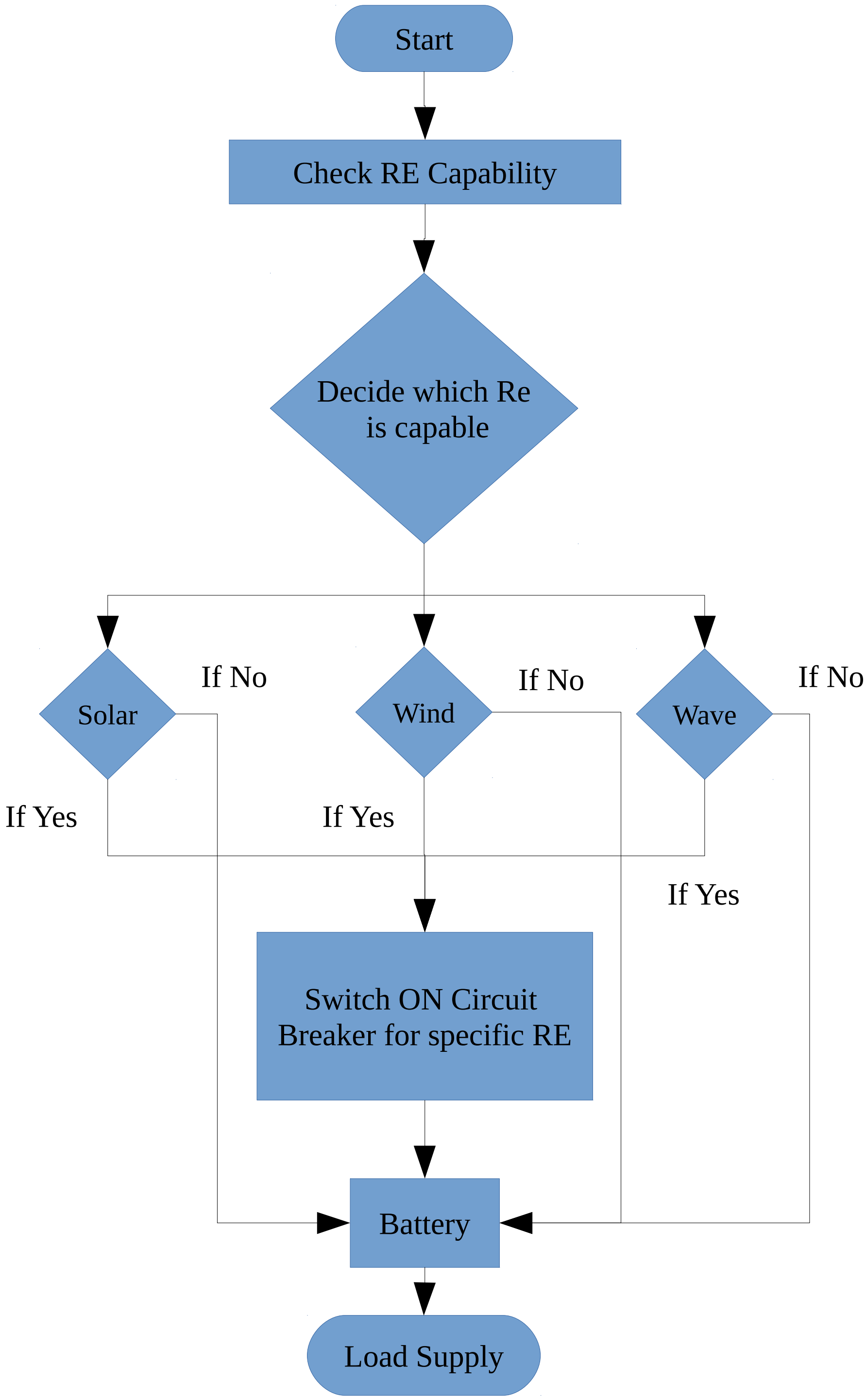

Figure 3.3: Flow of the Operation of the Centralized System

The operation of the system will be as the Figure 3.3. As we can see from the figure, the decision of which RE is used is based on the capability of the RE itself. This will determine which RE is the main supply to the load. By doing this, the switching if the circuit breaker will need to be control as to ensure that the load is given by a continuous supply.

From the Figure 3.3 also, we can see that, if all the RE is not capable enough in supplying enough power, then the system will automatically jump to the backup power which is in this case battery. Battery will provide sufficient power for a certain time before the other alternative appear or the RE is back in operation.

3.7 Capability of the Software and Hardware

As has been noted from previous subtopic, the execution of the operation need switching of the supply power. In order to do that, two options are available. First is to predict when and what to switch between the supplies. Second, when needed, decision is made straight-away and switching is occurring. In this study, author had choose the second options.

By all means, second options had push the author to design a very fast processing controller that capable in switching between the supplies to ensure there is no disruption to the load. Beneath, is the description about the method being use to ensure the fast switching decision.

Real-Time or RT Target

This method are means by it's name. Real time means that the configuration is executed in time or on time. Generally means by quick. But the trick here is the way we configure the responses to be in quicker way that commonly it is.

To point out, real-time operating system can be configured, so that it will be faster, in loop cycle time, jitter or deterministic. In the case of loop cycle time, a time is set to execute one cycle of a loop. If we can set the time for one loop, then all the actions inside the loop is executed within the specified time. Rather than, doing action-by-action with that time, same amount of time are use to perform all-in-one action in one loop. Hence, faster results is achieved.

By doing real-time, all the configuration can be done stand-alone. This is because the real-time target have it's own operating system. On the contrary, which is the desktop PC, operating system inside it have some more interrupt or priority to be executed.

This means that in each cycle of the loop, time are drag between the transition of the data to be process by the processor. This make the responses to become longer. Able to run in stand-alone mode, RT is suitable at the place where automated system is needed without the prior monitored by the operator.

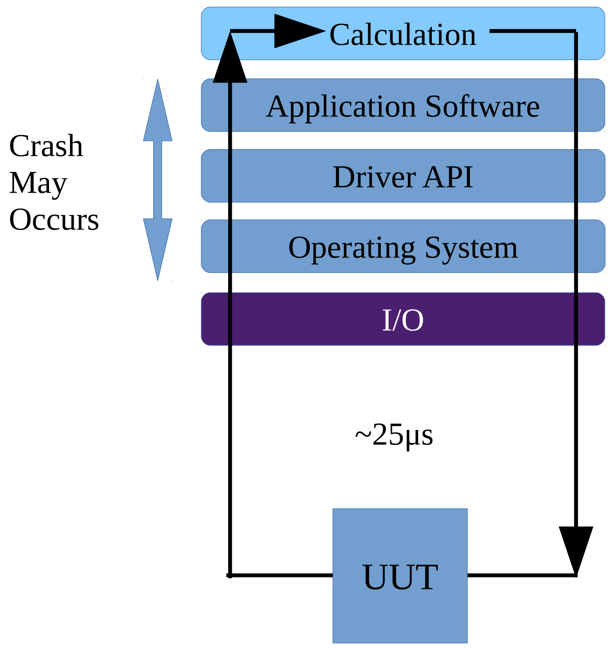

Figure 3.4 : Layer of the process data on Desktop PC

FPGA

Field Programmable Gate Array is just simply a chip with unconnected gates and other hardwired resources. With the programmable ability, user can define and re-define to suit the functionality.

The usage of FPGA some into picture when it goes to the need to have Fast I/O response. This makes more deterministic hardware using this kind of method to ensure that their hardware is functioning as fast as they can. With no CPU time sharing, FPGA makes decision based on the mapped gate that had been burn during the compilation of the chip. Hence, no more delays due to the operating system or application software. This faster response makes FPGA are reliable in handling the critical situation or some customized functionality.

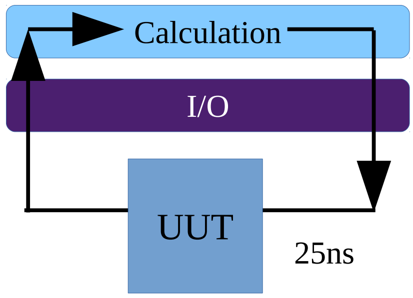

Figure 3.5 : Layer of the process data on FPGA.

3.8 Specification of the Equipment Used

3.8.1 Hardware

Real-Time Target

NI myRIO-1900 able to run in stand-alone mode. This is because of having the Real Time Operating System (RTOS) load inside the board itself. The configuration or the Virtual Instrument (VI) are deploy inside the board itself.

RTOS are store inside the Processor of the board. The board have build in processor from the Xilinx, model Zynq-7010. This processor are capable in running like a normal operating system due to the speed of the processor which is 667 MHz with dual core processor.

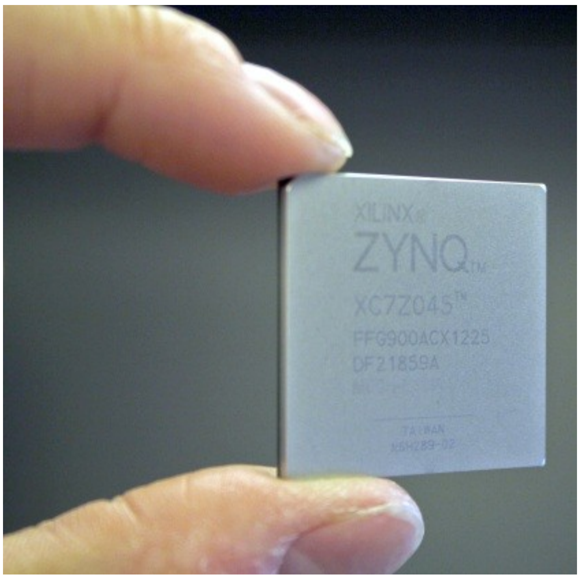

Figure 3.6 : One of the Zynq family use in many fast action devices

The complete block diagram of the myRIO-1900 Processor is shown in Appendix 3.

Built In FPGA

Inside the same processor also, build in, is the Field Programmable Gate Array (FPGA), model Artix-7 FPGA Family. Provided with types of memory such as flip-flops, block memory and look-up table, processing data are no longer required application. After burning the codes inside the gate array, the processing unit will do the calculation and decision at very fast speed. The FPGA also run in low power with a low cost to implement it.

Input and Output (I/O)

Input and output of this myRIO-1900 are capable enough is small and medium scale system. Two choices of input and output is in analog and digital mode. Two main way to connect the I/O to myRIO is by myRIO eXpansion Port (MXP) and Mini System Port (MSP). But both port have a slightly different capability in the analog control and monitor. Below is the explanation further about the I/O :

i. Analog Input – MXP capable in measuring as accurate as ±50mV that varies from 0 V to +5 V. While, MSP capable in measuring ± 10 V with respect to ground with ±200mV of accuracy.
ii. Analog Output – MXP capable in controlling from 0 V to +5V with accuracy of 50mV while MSP can controlling ±10V with the same accuracy.
iii. Digital – Input : capable in obtaining status of high and low when range of voltage is determine. For high, min is 2.0 V with max of 5.25 V. Output for giving high is max of 3.465 V and not less that 2.4 V. For writing zero or low value, the output need to be in range of 0 V to 0.4 V.

Power Consumption

To operate the board, power supply is needed. The DC supply varies from 6-16 V are enough to operate the device. In maximum usage of the device, it will consume in maximum of 14 W. In idle state of the device, the power it will consumed is 2.6 W.

3.8.2 Software

To configure the device, software from National Instrument are needed. To be specified the software is LabVIEW 2014.

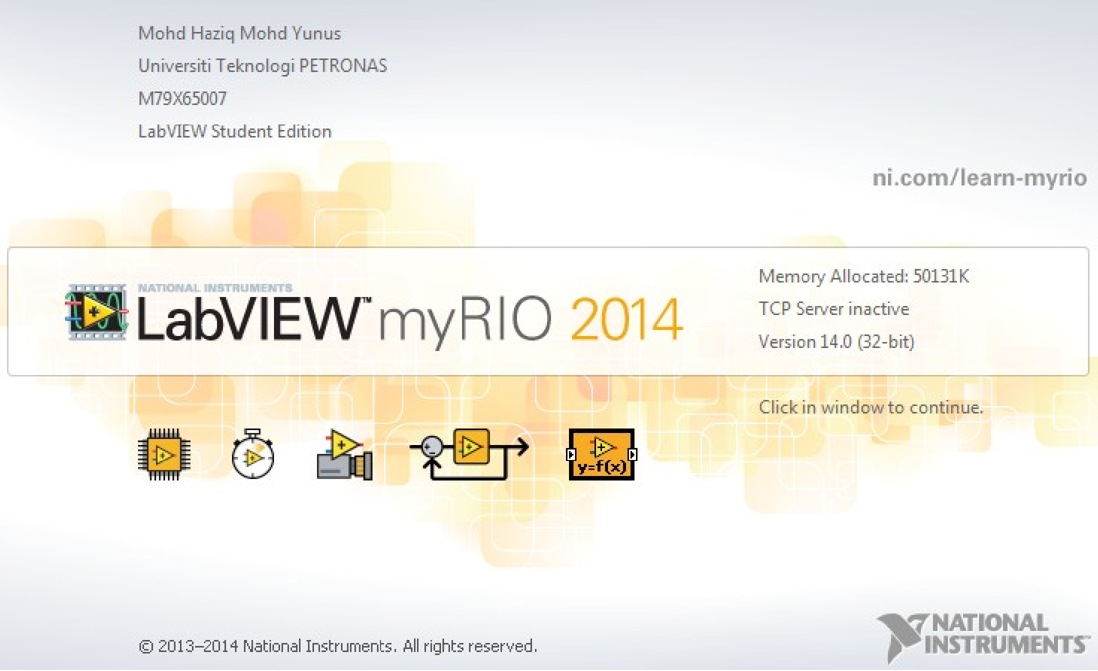

Figure 3.7 : LabVIEW myRIO Software

LabVIEW myRIO 2014

The software is needed to program the device. A development PC is use to develop the graphical programming. Not so much different with the code programming, graphical programming are tend to be more manageable and not confusing. Graphical programming also help in giving an easiness in configuring a desired implementation.

Both simulation and also operation can be done on same software. But the program to load are bit different when dealing with desktop PC, RT target and FPGA target. Accessing the data or value from one target to another also have Standard-Of-Procedure (SOP). This is due to the different in the speed of the processor. For instant, Desktop PC may have faster processing speed rather than the RT Target and FPGA. Unfortunately, when in operation, desktop PC tend to have more parallel operation and interrupt. This produce delay in executing any code. Hence, timing in programming are takes into consideration.

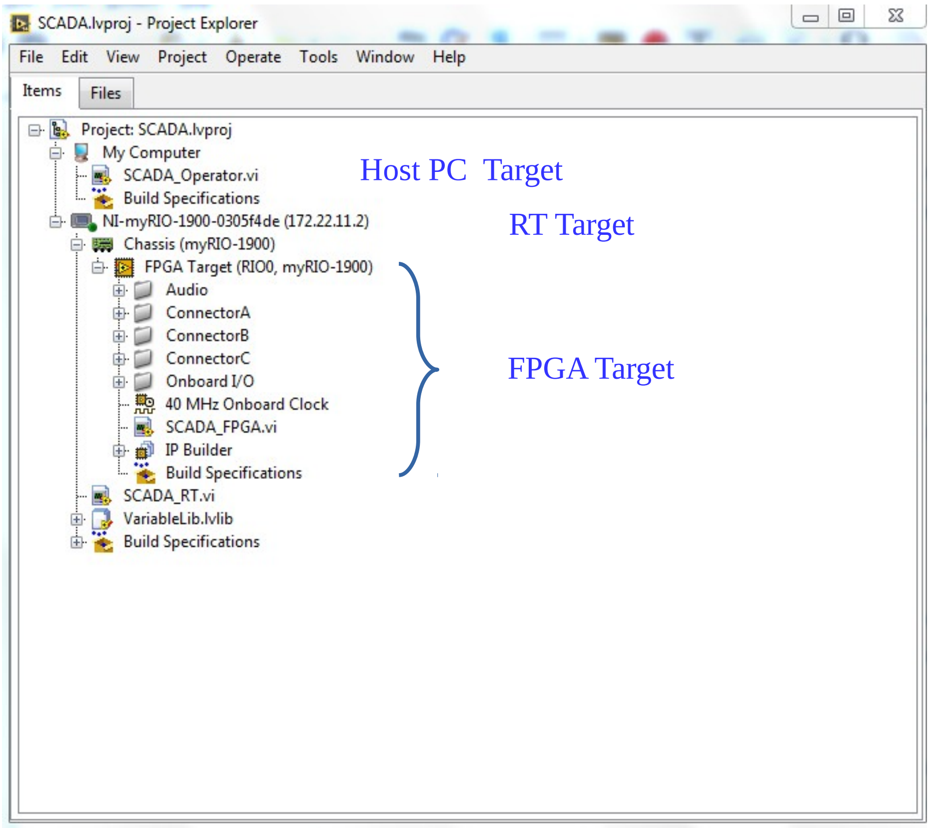

Figure 3.8 : Project Explorer shows the different target that required different operating software

LabVIEW Real-Time

LabVIEW real-time are needed in making the RT target to work. Indeed, the it will be as RTOS when we deploy our program inside the RT target. LabVIEW real-time only appear to the section of the project explorer in which a devices had been connected to it. In normal mode or in normal LabVIEW 2014 programming RT target cannot be configured.

In order to do this, variable are needed to shared among the different target. Such variable that exist are the FIFO or First in First out. This variable will be stored in memory, in this particular case it is a DDR3. DDR3 is types of Random Access Memory (RAM) that is used to stored temporarily value or data while waiting to be process. In myRIO, the DDR3 sizes is 512 MB.

LabVIEW FPGA

This is the specific software that use to program the FPGA. Usually, the FPGA is use in critical situation. Hence, the configuration of this FPGA will only be a short, precise and fast without great buffered.

In advanced, to program the FPGA, Single Cycle Time Loop or SCTL is use. The different between SCTL and normal loop is, SCTL only required one cycle to complete all the task inside the loop while normal loop may take more cycles to complete one loop. If calculating in transient mode, the SCTL will execute much more faster that the normal loop even though same iteration had been complete.

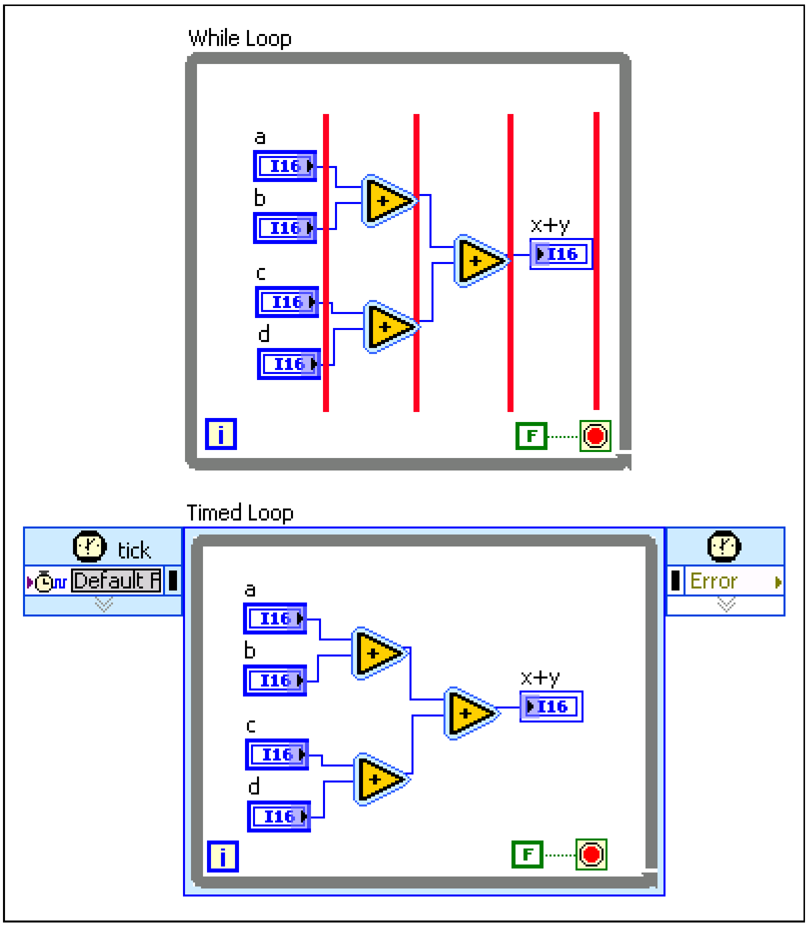

Figure 3.9 : Different between the normal while loop and timed loop

As can be seen at the above figure 3.8, while loop and time loop have same task to accomplish. If considering the while loop, the red line indicate the cycle needed to done the specific task. Four red line means that 4 cycle is needed to complete the loop.

While the Timed Loop, all the task or operation are execute at one clock rate means by one cycle. If we do calculation to the time taken for the completion of the task, the normal while loop will take 4 times longer that time loop. Hence, the advantage here is the utilizing the clock speed to accomplish the simple task.

However, some of the task may required more than one cycle to complete. Here, the Time loops cannot be used, instead, variable are use to reduce the time taken for the task to complete.

Configuration of the FPGA needs more structured programming. This is because of the function of using FPGA itself. We do use FPGA to optimizing the responds rate of the device. Hence, the more function we put inside the FPGA, the more time taken will be needed. Instead, only the critical action are programmed in the FPGA.

Chapter 4
Result and Discussion

4.1 Results

HMI

The generated HMI from the LABView is almost the same with the other SCADA HMI. The real time value of the voltage are displayed. LABView Operator Panel HMI is shown in Appendix 4. The configuration is deployed into a controller or so called myRIO-1900 from National Instrument.

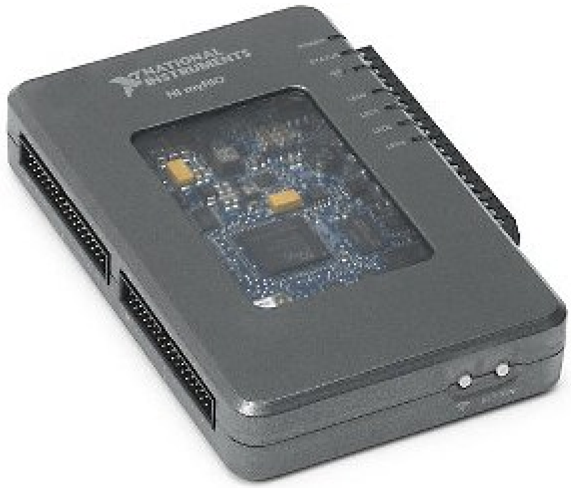

Figure 4.1 National Instrument myRIO-1900.

Operation

As according to the Flow of Operation in the methodology, the system now are comparing the voltage input. From here, then the system will decide which of the RE are capable in supplying the voltage to the load.

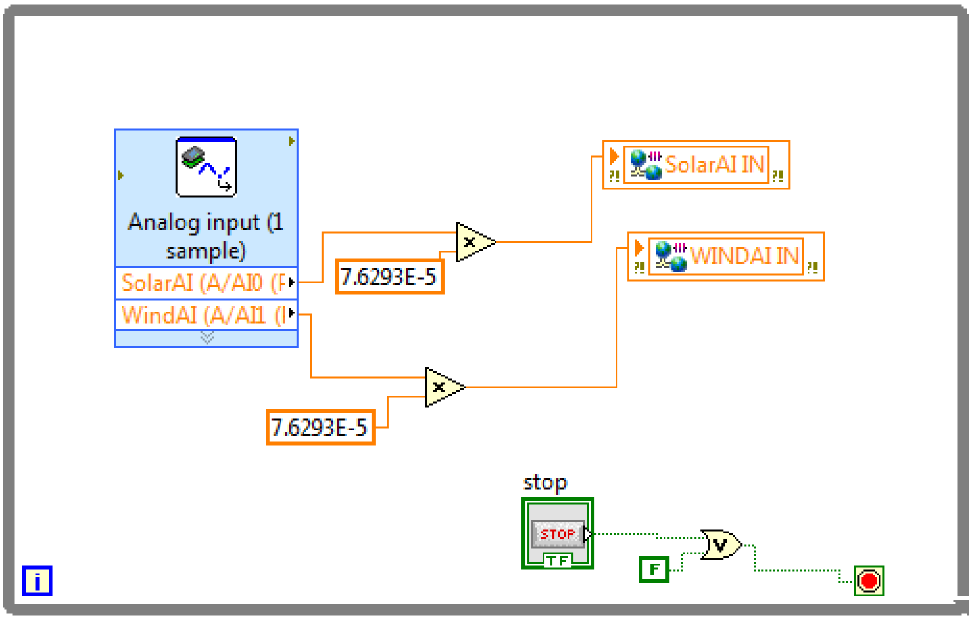

Figure 4.2 : Analog Input Signal from the RE

As we can see from the above figure, the signal from the RE, which is we assume that the power is converted to normal supply rating, 230 VAC and 50 Hz, is step down to reasonable value. This is due to the ability of the controller to measure the voltage at very low value compared to the original signal. From the step down signal, the value that will be read to the system is from 0 to 5 Volts. The full percent or 5 Volts is when the voltage are at good condition which is 230 VAC. If the RE is not capable in supplying power or maybe shut down for the reason of cannot generating power then 0 Volts is appear.

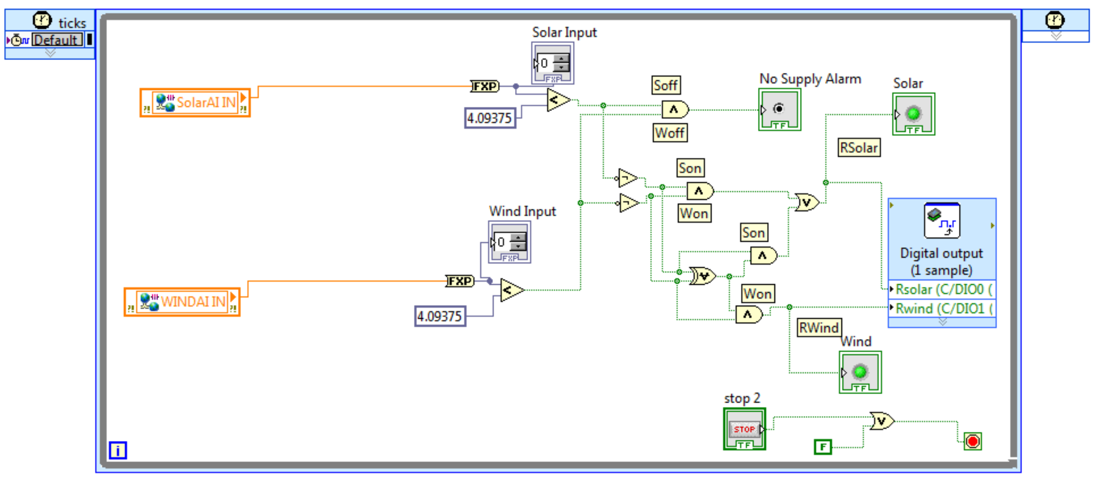

Figure 4.3 : Priority Supply Operation

As for the figure 4.3, the block diagram shown is how the signal is processed. Priority are set to the most stable one which is in this study, solar panel. Second is the wind generation. When both are capable in supplying to the load, the solar in choose. In either way, if one of it can supply, then the other capable supply will take over the task.

The indicator of Solar Input and Wind input then transfer or shared to the other VI. This value indicates the value of the step down voltage. The value then will be process by the other VI which is less critical task in RT target.

Decision Making

The decision to determine which of the supply will provides the power is made also at the figure 4.3. The case of the operation is illustrated in table below.

Table 4.1 : Decision Making Table

Solar	Wind	Decision of Power Provides
On	On	Solar
Off	On	Wind
On	Off	Solar
Off	Off	Alarm Triggered

The sample of the operation shown in the table 4.1 is much more similar to the Cause and Effect Diagram technique. To implement it, the value of which the on and off is indicate is compared. The next illustration enlighten the meaning:

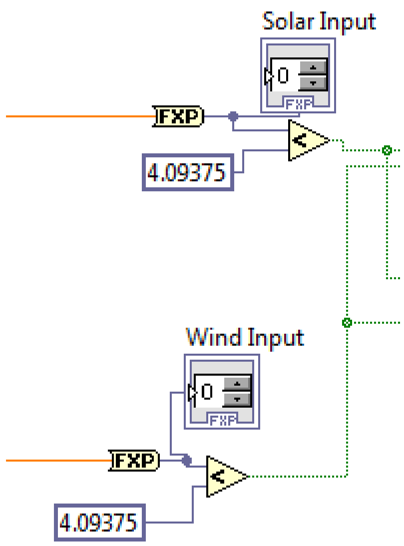

Figure 4.4 : Comparison of On and Off

Input from the Solar Analog Input is compare to the value that can be consider that the supply is going to off. The return of the comparison is true. If the signal is above the value then false if return.

For the first case, when both supply are on, then the boolean comparison is made as shown below:

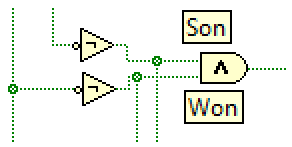

Figure 4.5 : When both supply are available

According to the figure 4.5, the supply which false after the input comparison is inverted to true. This indicate the supply is on for both. Next, the true value is multiple together using AND gate. If the value return true, means, both of the signal are in on state.

For the second case, which when the solar panel is off and the wind turbine is one, the comparison should return according to the next illustration :

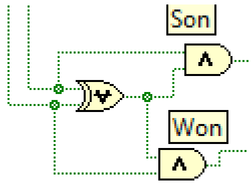

Figure 4.6 : When either one is On

From the figure 4.6, when the signal of solar or wind is On while the other are Off, the return of the Exclusive Or is true. For the case of the solar is Off and the wind is on, the true value from the Exclusive Or is compare to get a true value with the value of the original boolean of the wind. If it return true, then, the decision is made to allow the wind to supply to the load.

Some overlapping happen among the case 1 and 3. To solve it both boolean return in each case is compare by following illustrations :

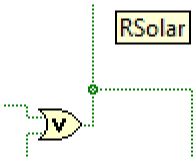

Figure 4.7 : Comparison of Case 1 and 3

The Or gate is use to make the return true. Means, if either one of the signal giving the true value, then, the Solar Panel will be allow to supply power to the load.

Switching The Supply

The switching of the supply is makes after the decision done. If the Solar Panel is allow to make supply to the load, then the Digital Output will be triggered to closed the switch that will allow the supply to distribute to the load.

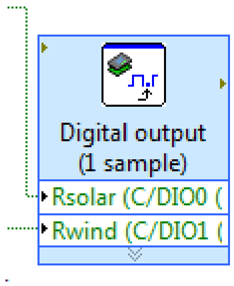

Figure 4.8 : Digital Output Write to Triggered

The Digital output (DO) will give a true signal that also denoted as 3.465V. This signal is going to the switching circuit to allow the magnetic contact to close the switch.

In this study the switch use is magnetic relay. The output signal from the DO will triggered a transistor to make the way to the input supply to magnetize the coil. Once the coil is magnetized, then, magnetic contact will reflect to the magnetism of the coil.

Connected to this circuit is usually open switch. This means that the triggered signal is needed to make contact to close the switch. Hence, the Digital Output make the reaction possible.

Historical Data Collection

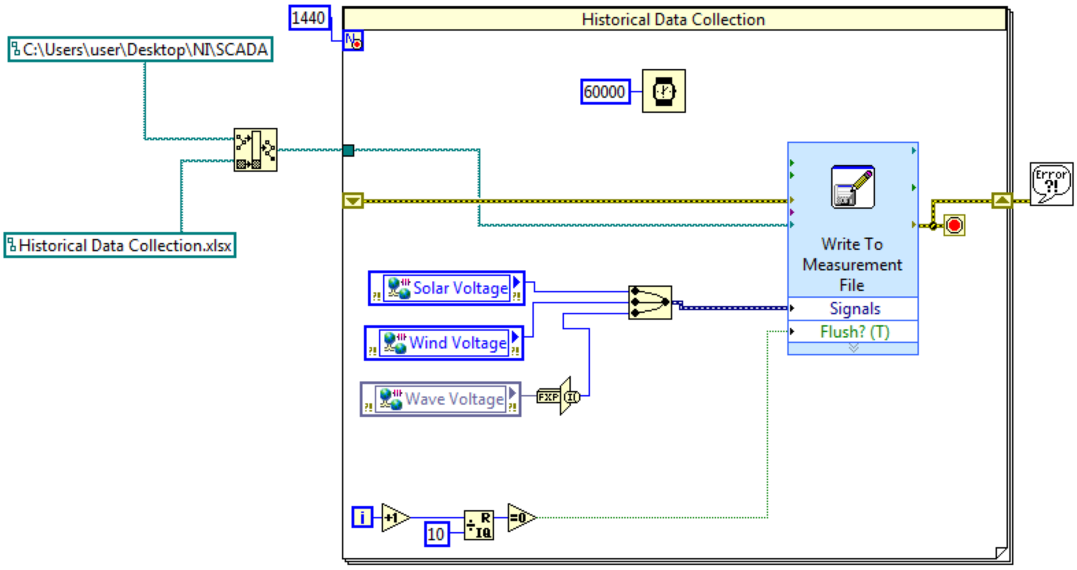

Figure 4.9 : Historical Data Collection Block Diagram

In order for the system to be more reliable, the system are storing the value of the monitoring data to the workstation connected to it. By implementing this then the time and data and value are stored to be used in future. Then, in each month for example, the data are plotted in a graph to see which of the RE are the most stable in supplying the power.

From the Figure 4.9, we can see that the data from the signal input is stored in a spreadsheet. By performing a delay in each storing data, then the data can be stored in each minute. The block diagram is working for the 24 hour period time. So, the history of each day can be stored for the future reference.

Alarm

When neither of the supply are not capable in supplying to the load, then the alarm will appear at the operator front panel. This will help to tell the operator to take an action towards the event. The configuration are also based on the figure 4.3 with the addition of block diagram to appear on the front panel, shown below :

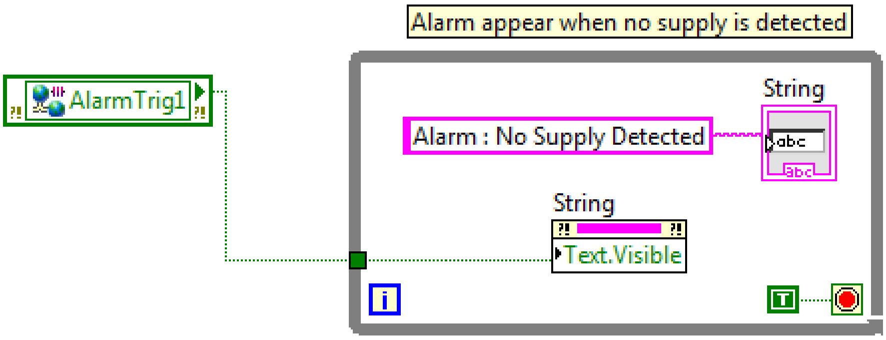

Figure 4.10 : Alarm configuration

Signal Processing

The signal receive is the step down value. The signal is in the analog value of unsigned integer with 16 bits. The value that is obtain from the I/O is the raw value. Which the value need to be calibrated to get the correct value in reality.

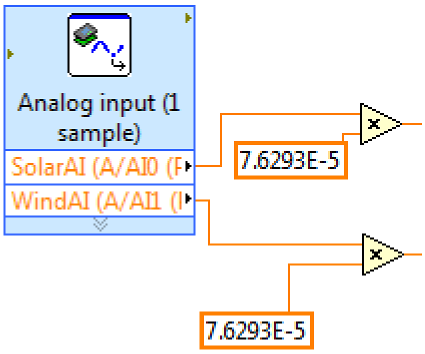

Figure 4.11 : Calibration calculation

Calibration calculation is obtained from below equation :

$$Highest\ Input\ Signal = 5\,V$$

$$Resolution(bits) = 16\,bits$$

From the above given value, Least Significant Bit (LSB) is determine by dividing both of the value.

$$LSB = \frac{(Maximum\,Voltage)}{(2^{(bits)})} \qquad \text{Equation 4(1)}$$

$$LSB = \frac{(5\,V)}{(2^{16})}$$

$$LSB = 0.000076293\,V = 0.076293\,mV$$

The equation 4(1) is use to obtain the LSB. The LSB then is the value of one step of the resolution.

$$Total\,Resolution = 2^{16} = 65536$$

$$First\,Resolution = 0$$

$$Last\,Resolution = 65535$$

The LSB is then multiple with the resolution obtained from the analog input. The product of the multiplication is the exact value from the field.

RT Target Processing

The RT Target will process the input signal from the FPGA input. To obtained the input signal from the FPGA, some SOP is done. The extraction of data need to open the VI of the FPGA and process before close it back for the other to use it.

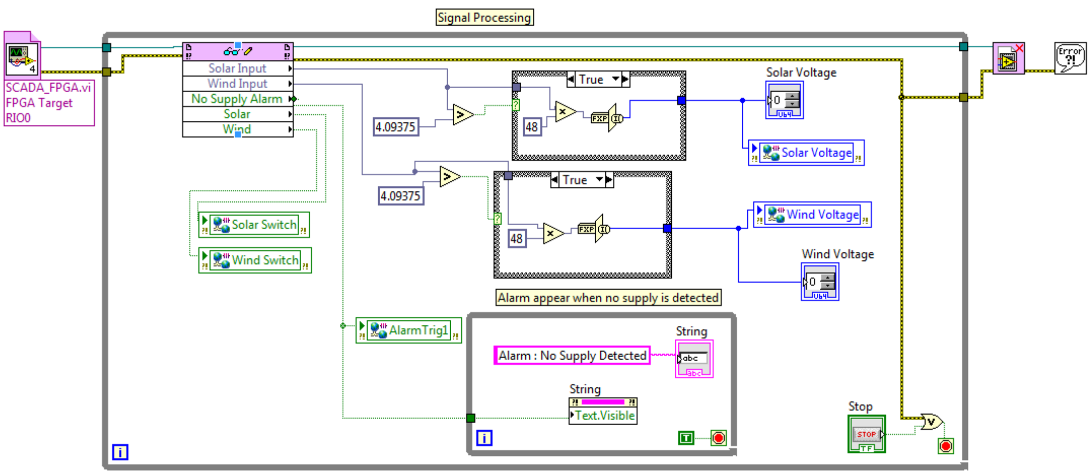

Figure 4.12 : The SOP of obtaining the value from FPGA

Due to the step down signal, to get the original value of the supply, ratio of the step down is multiplied to the input signal. The illustration below shown how it is done :

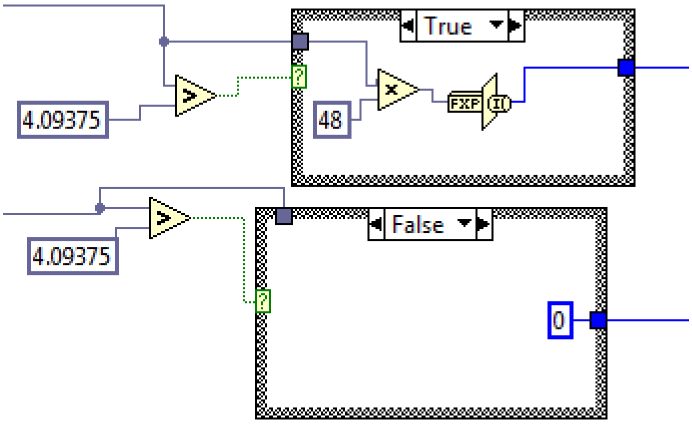

Figure 4.13 : Multiplying to the Ratio

From the above figure 4.13, the signal obtained from the FPGA is once again compared to get the true case or false. If the true case is obtained, then, the value will return with multiplication with the step down ratio. If the opposite value, false is obtained, zero value will be return. This is to indicate that the supply is in Off state.

The Control Mechanism

The switching is needed to control the output. In this study, the author had used the switching technique of transistor. Although, more fast switching device can be obtained, the cost consideration is still need to take into consideration.

In this case, the Bipolar Junction Transistors or BJT is used. The other words to describe the BJT is voltage switching, current sourcing. Hence, at the triggering part of the BJT current need to be introduced. By applying the Ohm's Law, then current is produced through the resistor. The basic circuit construction are as followed.

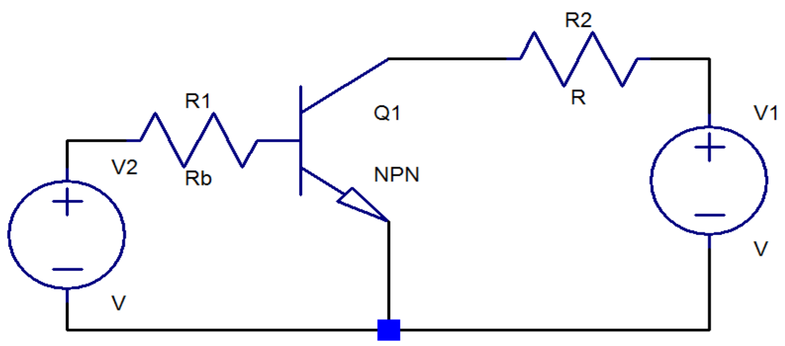

Figure 4.14: Basic switching circuit of NPN transistor

In the figure above, the Rb is present to ensure that the current is source to the base of the transistor. For the controlling capability, the V_2 will be replace with the Digital Output of the micro-controller. To turn on the transistor, 5V is supply to the R_B, while 0V is supply to the R_B to turn it off.

Meanwhile, to ensure that the Transistor is fully on, the current through the R_B, which is I_B need to be large enough. The I_B is depend on the value of the I_C and the dc current gain of the device or h_{FE}. From the equation below

$$I_B > \frac{I_C}{h_{FE}} \quad \text{Equation 4(2)}$$

Since the author use transistor for ZETEX, model ZTX 450, according to the data-sheet, the minimum I_B need to be introduced is 1.5 mA. This value can be easily supplied from the myRIO-1900 since the capability of the Digital Output of the myRIO itself can provide almost 4 mA. For the information, the Analog output of the myRIO also capable in sourcing that much of current which is 3 mA.

In the case of the current is not enough to introduce the saturation region of the transistor, higher value of the resistor can be added. Such calculation to determine the value of the resistance need can be obtained from the next equation:

$$I_B = \frac{(V_1 - V_{BE})}{R_B} \quad \text{Equation 4(3)}$$

As we discussed the turn on capability, at some point the switch must go off for some reason. The off characteristic of the BJT is simple, which is by supplying negative or zero voltage. From the figure below the characteristic of the switching can be seen more clearly in transient mode:

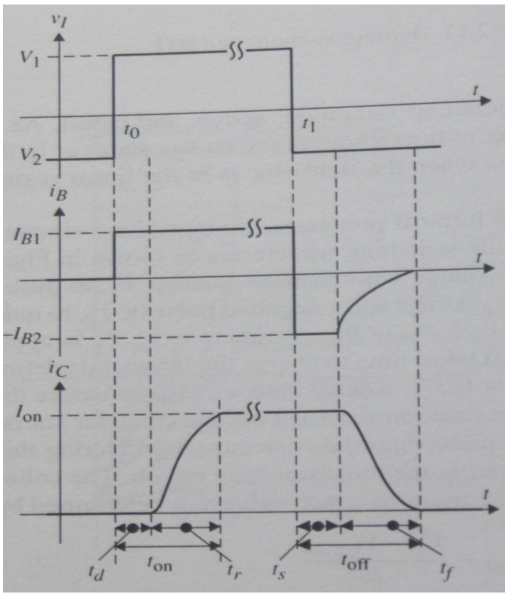

Figure 4.15: Switching Waveform of the BJT

As seen in the figure above, the switching off of the BJT have not be ideal as it should. This is because of the saturation characteristics of the device itself. The collector current which should discharge as there is no more current being introduced at the base, does not decreasing. The collector current will discharge after the saturation charge had been removed. This time period for the removal is call saturation time, t_s. This is the drawback of the BJT in operating in saturation mode, which is the easiest way to operate the device.

For the purpose of improving this, a technique so called Baker Clamp is introduced. Next figure is the configuration of the Baker Clamp technique to the transistor.

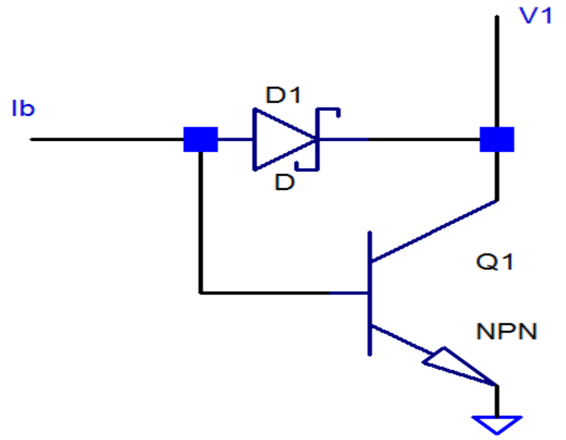

Figure 4.16: Baker Clamp circuit basic implementation.

The circuit design is to ensure that the Schottky diodes forwarding voltage is less than the V_{BE} of the transistor, voltage drop across base-emitter. The schottky diodes will be on when the saturation point is triggered. This give the negative feedback to the collector. Preventing the transistor to be more saturated.

As the case are occurring in transient, it can be neglected if to short of time are involved. In consideration to shorten the time of respond, another type of switch can be use or combination technique could be use. Electro-Mechanical Relay(EMR) and Solid State Relay(SSR) are some of the example.

Relay are use as the isolation switch from the line to the load. Relay also functioning as a decision of on and off for having two cases that acts in different situation. Different from the SSR, EMR use coil to control the open and closed of the triggered part. An input signal rated by the relay itself must become true to ensure that the switch is magnetized for closing the circuit. Since the EMR are using the technique of magnetization, inductance inside the relay is present. With attention to the inductance, power factor are present. Inductance produce a lagging power factor which added up the respond time of the switching or control.

Meanwhile, the same case in SSR in reduced and much more better. This is because the magnetizing part are eliminated and replace with the electronic part that can respond faster than the EMR. Rather than working on in milliseconds for EMR, SSR took about nanoseconds to react after the triggering signal is emerged at the input terminal.

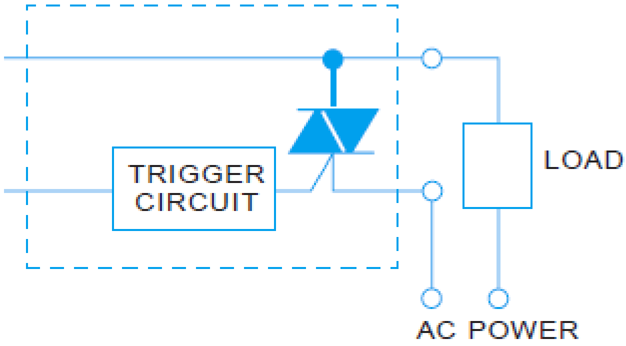

Figure 4.17: Internal circuit of the SSR

Figure above showed that the internal diagram of the SSR. The triode for alternating current or TRIAC are present at the switching side. The TRIAC is functioning as the allowed mechanism for the load to closed the circuit. To operate the TRIAC, it has to be triggered. Once the triggered success, than the TRIAC can allow the AC to flow which is in bidirectional direction.

The triggering signal of the SCR is from the micro-controller. Once the micro-controller decides that the SCR can closed the circuit, then, the triggering signal in present at the SCR input. The input signal also are micro-controller friendly, which is in low voltage requirement. But, in the application, current from the micro-controller might be not enough. Hence, some approach are done such as combination of the transistor switching and the SCR control mechanism, which in this study are decided to approached.

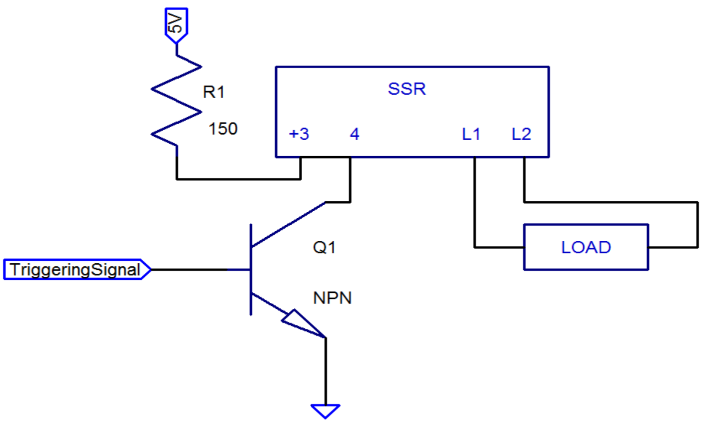

Figure 4.18 : Control circuit setup

The Monitoring Mechanism : Analog Input Versus Digital Input

Together with the National Instrument myRIO-1900, the hardware are build in with the Analog Input (AI) and Digital Input(DI). The single wired and double wired analog input will suit to the need of precision or the low input according to the configuration. The Digital Input in the other way, are more easier in configuration but may have some drawback in the aspect of the sensing speed.

To emphasize to this comparison, the most suitable one is the monitoring system. Theoretically, the monitoring will be used as the reference to the controlling mechanism for the automated system. The sensing device will detect the input supply to decide that if the supply is there to draw power to the load. If the sensing device successfully detecting the input, then the supply might be the main in supplying the power. In opposition to that, the other supply may be triggered to draw power to the load.

Important to realize, that the sensing device is step down the voltage of the input supply to more appropriate value for the myRIO to measure. As the assumption is made, that the input of the supplied is standard rated 3-pin plug, 230 VAC, 50 Hz, the step down of the voltage would be to the 5 volts. The reason to step down to 5 V is just because of the capability of the analog input in measuring the voltage, range from 0 V to the 5 V only using myRIO eXpansion Port(MXP). Additionally, myRIO also have the rated analog input range from the -10 V to +10V connected through Mini System Port(MSP). But, the MXP in choose rather than MSP is because of the absolute accuracy of the measurement. MXP have the absolute accuracy of ±50mV, while in the other hands, MSP have absolute accuracy of ±200mV. By this specific value, the MXP is much more precise than the MSP.

Then again, the sensing device is actually an analog value. The digital input are capable and can read the value of the sensing device due to the suitability of the measurement. The sensing device are using conversion from the AC to DC. Some rectification are also a part of the step down. Hence, the output of the conversion have some capacitance. In application of the supply to the low voltage load, this capacitance act great where the ripple signal could be eliminated. But in the sensing application of the monitoring purposes, the capacitance will lag the detection of the supply.

Most compelling evidence is to take the transient value into consideration. Figure below illustrate more about the topic discussed.

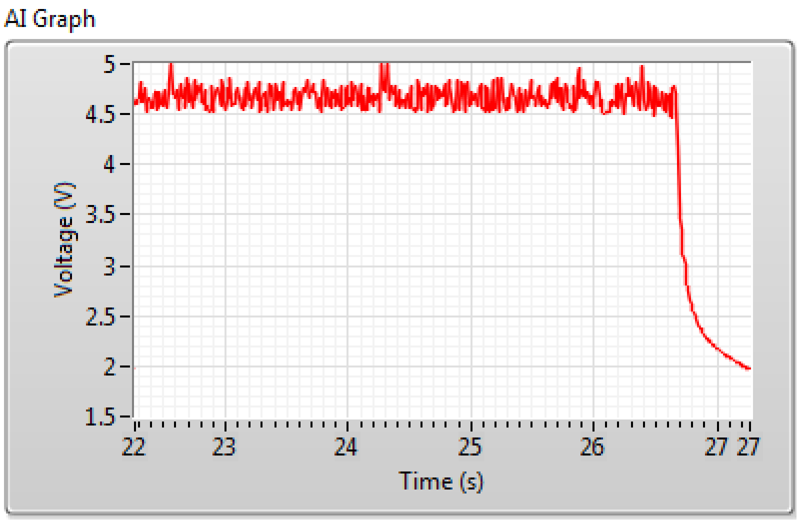

Figure 4.19: Analog Input graph showing the input voltage in transient mode.

That is to say the measurement are lag. As we can see in the above diagram, the time indicate the supply are detected for certain period. A range of signal is measured and ripple are detected during the normal operation of the supply. In the case of power is not enough or might be trip, then the signal will tremendously drop to nearly zero voltage. But drop in value drag some of the time.

As the result, if we are using Digital Input as voltage monitoring, some lag occurs in detecting the trip condition. Hence, the other decision made after that will also drag the time. To ensure that the time is reduced, an analog signal is used.

Provided that the analog signal are measuring the value in continuity mode, then, every value of each short time can be measured. Hence, the solution to the time drag of the digital input is solved by comparing the input signal to decide whether the trip condition had occur. Decision based on the comparison is when the signal is exceeding certain value that can be considered as trip condition.

For instant, the figure above show more specific value. The normal operation of the supply will measured as the signal is range from 5 V to 4.4 V. If we are using digital input, the low condition is from 0V to maximum of 2 V. Whereas the analog input are detecting the continuous signal. Then, we can configured that when the signal is less that 4.1 V then it is considered trip condition. Then, decision should be made that the other supply should replace the priority.

Circuit Arrangement

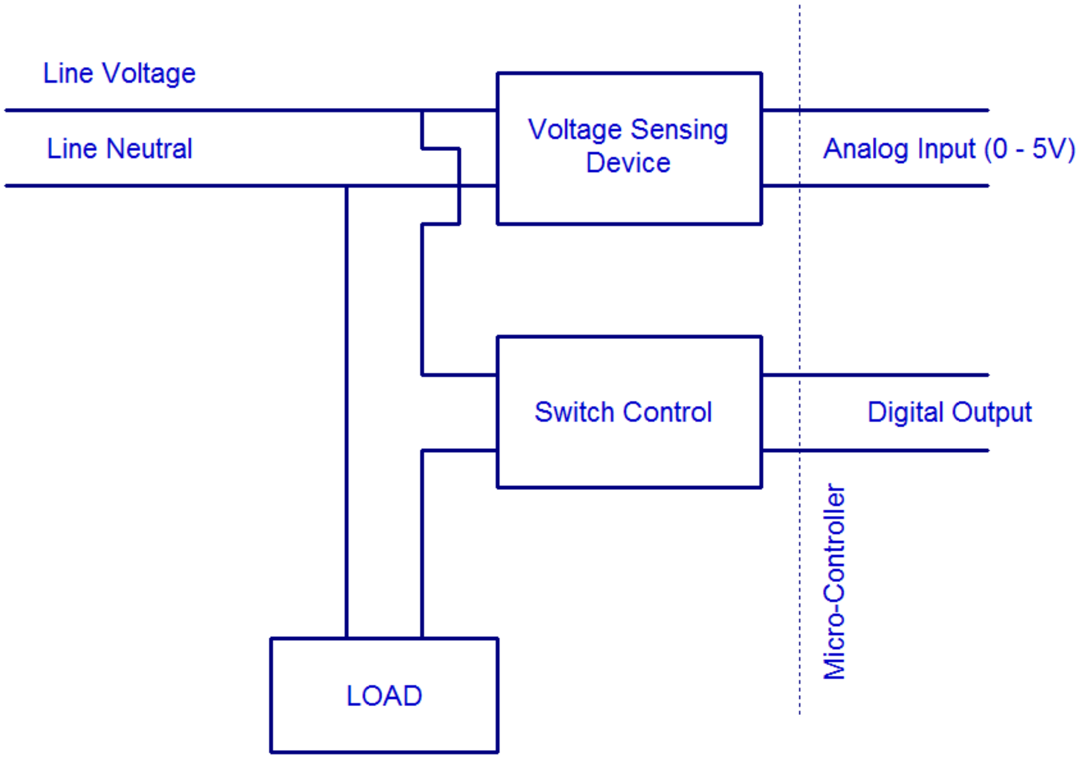

Figure 4.20 : Circuit implementation

The arrangement of the circuit are as figure 4.20. Overall circuit consist of monitoring and controlling mechanism. The monitoring of the system get use the voltage sensing device while control mechanism get use the switch control. The monitoring is read from the micro-controller and control are triggered from the micro-controller.

For the LabVIEW all configuration code, Appendix 4 is attached for reference.

Chapter 5
Conclusion

The emerging technology of RE made the world glare seriously which regard to the ability of this free-cost power generation. The best method in extracting the power is when the RE is integrated to each other. This will ensure more power being extracted. As it is in study phase, the RE only implemented at the area of low demand power. Soon, when the system are stable and able enough to provide power to the grid, this system are no longer be side power provider anymore. As for now the RE is only the best choice for the Distribution Generation or DG of the grid.

The development of this integration system will help other who are working in this area for years, to simplified the consideration factor in developing the system by managing the sources of power. Also, will contribute in giving ideas especially in the energy management of the RE. This integration system are optimum to be applicable at the building that does not have heavy load to handle especially heavy duty motor machine. If the IRES is developed in a low cost, then the possibility that this system to be implement in residential area is high, especially in the rural residential area.

Instead of having the predictive decision, this study is done by comparing the input supply. If the supply available and capable in supplying to the load, then, according to the priority sets, the supply will be allowed to makes supply. If not, the other supply will be use as the source of power to the load. The decision makes in fast reaction. Means that, the decision is make within the time that the interruption will not occurs.

Recommendation

For future works, in improving the system, the author would like to recommend for much more precise and accurate data acquisition.

For more precision in decision making, the sensing device need to be more precise and much more faster. In order to make that happen the sensing device should avoid to have biggest capacitance or inductance value. This is because if the this non-linear characteristics exist in the sensing circuit, the reaction time of the sensing device will be longer. The longer the sensing device needs to detect the real situation, the more chances for the load to have interruption of power.

In instant, the existing configuration are automated, which is good for the case of stand-alone application. For some reason, if the supply is always put the availability to the same sources, it will create burden to the supply. For example, when same supply is used, load may drag more current from the source. More current means more heat dissipated. This heat, if it is too long time of exposure, then, the insulation of the supply's cable may infected. Hence, the life span of the sources will be reduce. That also leads to maintenance or replacement action.

In this study, the respond time of the micro-controller can be more faster. During the study is done, the configuration is based on the Real-Time system. The author wanted to do at very fast level which is the FPGA level. Unfortunately, the duration of the study are not enough, added with some good practice in configuring the FPGA to make it work well enough. As for recommendation, in improving the respond time of the system, FPGA configuration should be done in the future.

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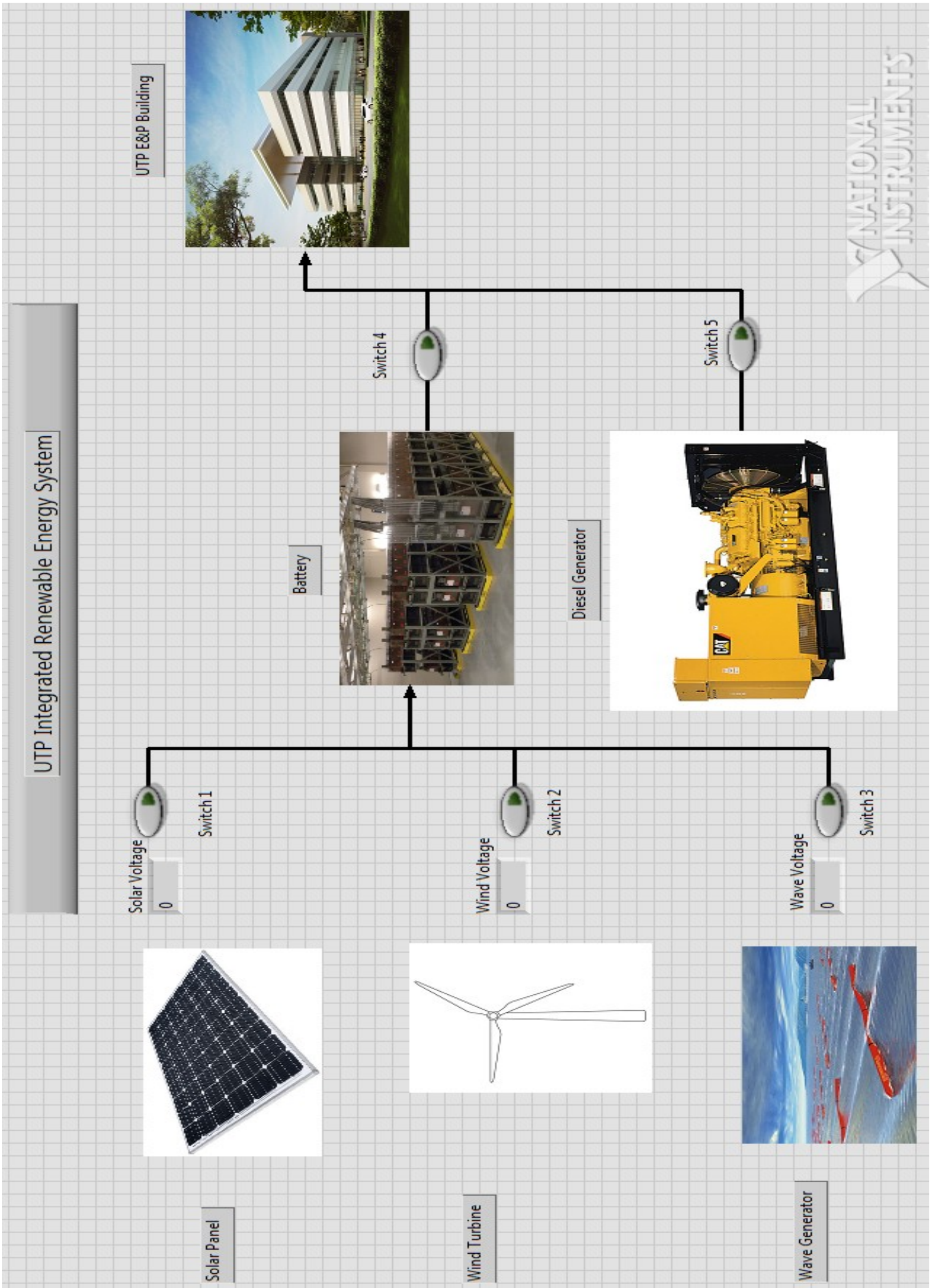
Appendix 1

Table below shows the Gantt Chart for the project accomplishment.

		Period (Week)													
Phase	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Design	Finalize the types of RE	■													
	Research on the IRES		■	■											
	Power Flow Study				■	■									
	System of Distribution						■	■							
	System Implementation (Phase I)							■	■	■					
	Software Simulation										■	■			
	Hardware Preparation												■	■	
Implementation	System Implementation (Phase I)	■	■	■	■	■									
	HMI Development						■	■							
	Safety System								■	■					
	Alarm Management									■					
	History Data Collection										■				
	Synchronization of System										■				
	System Simulation											■	■		
	System Modification												■	■	

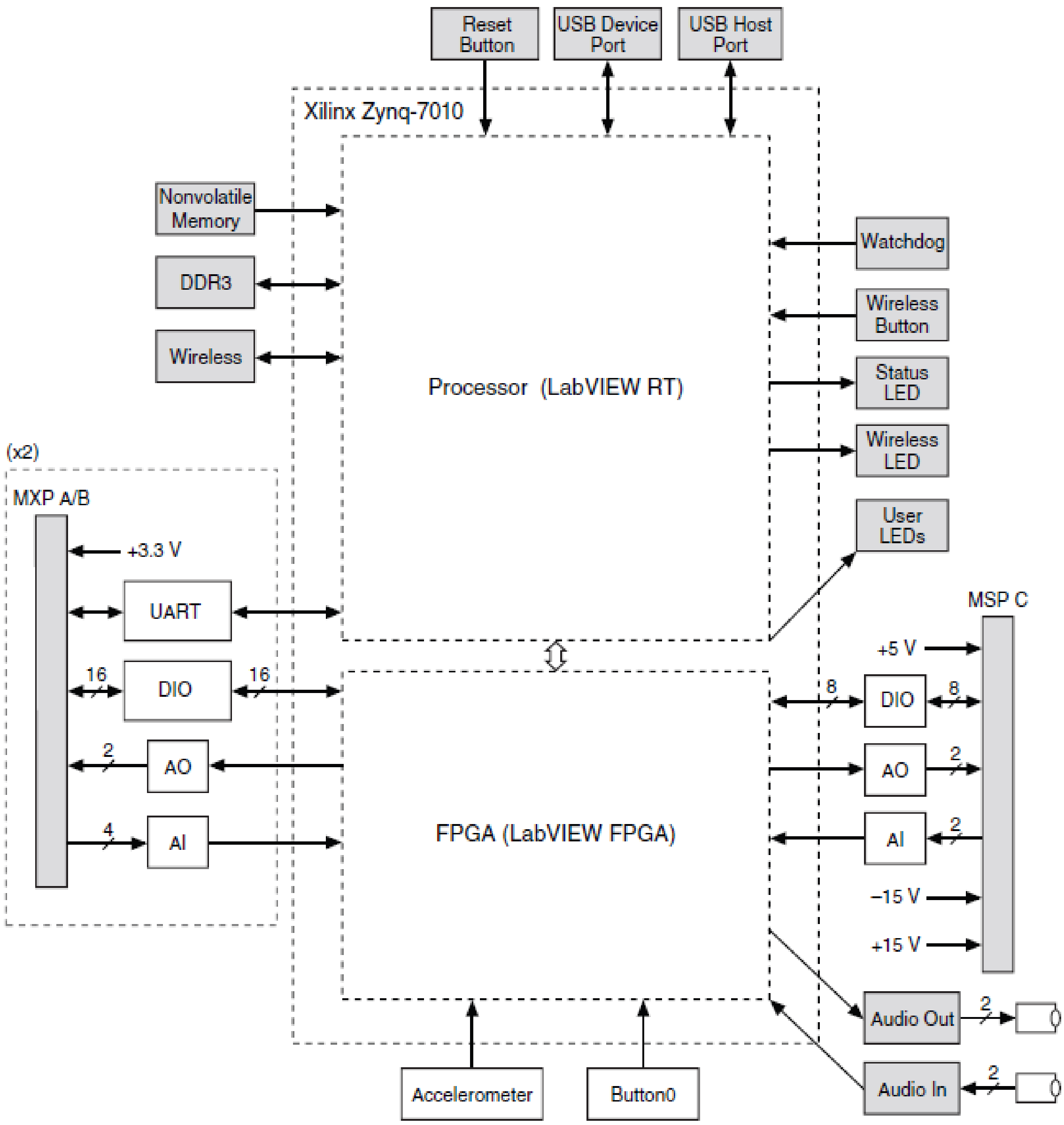
Appendix 2

HMI of the LabVIEW Front Panel



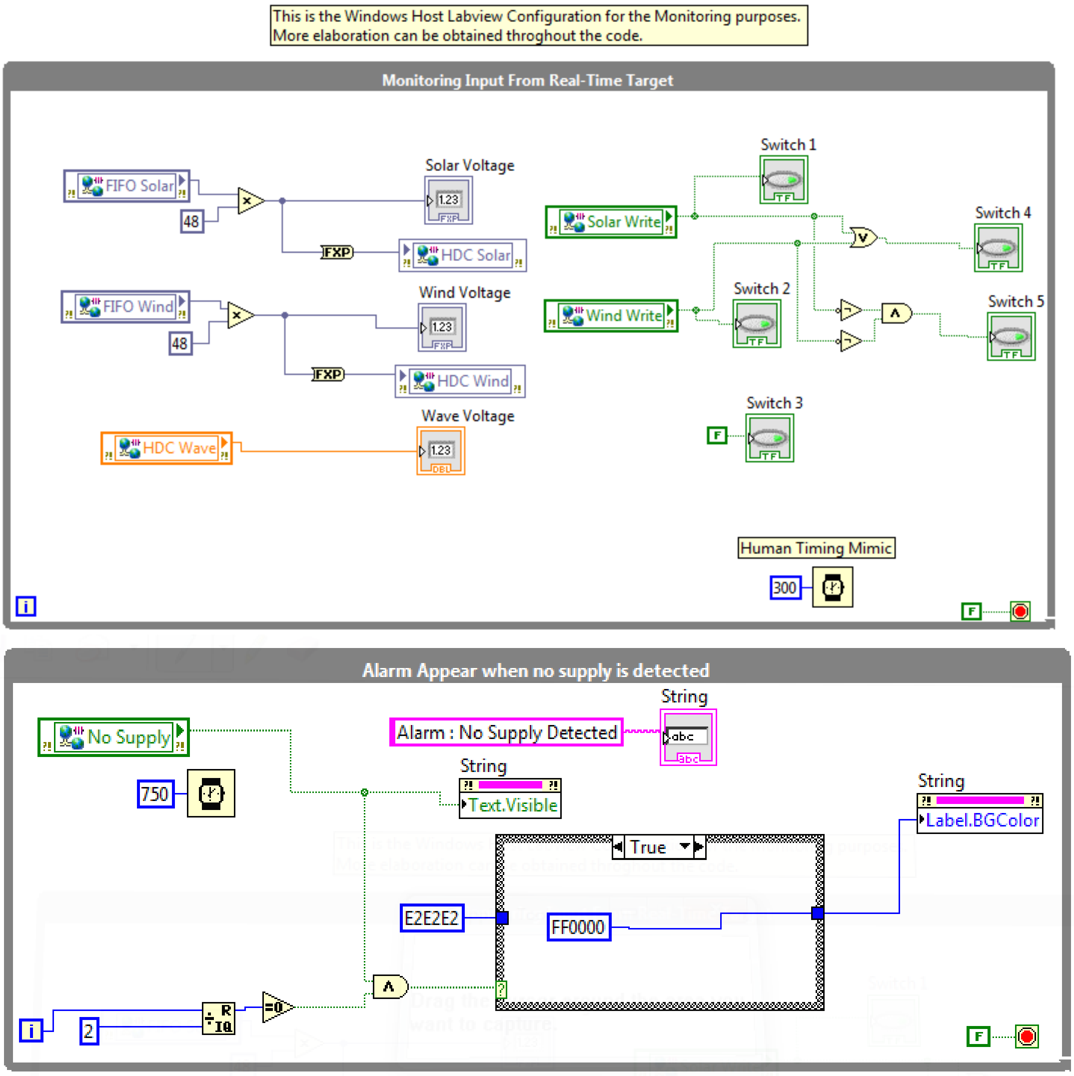
Appendix 3

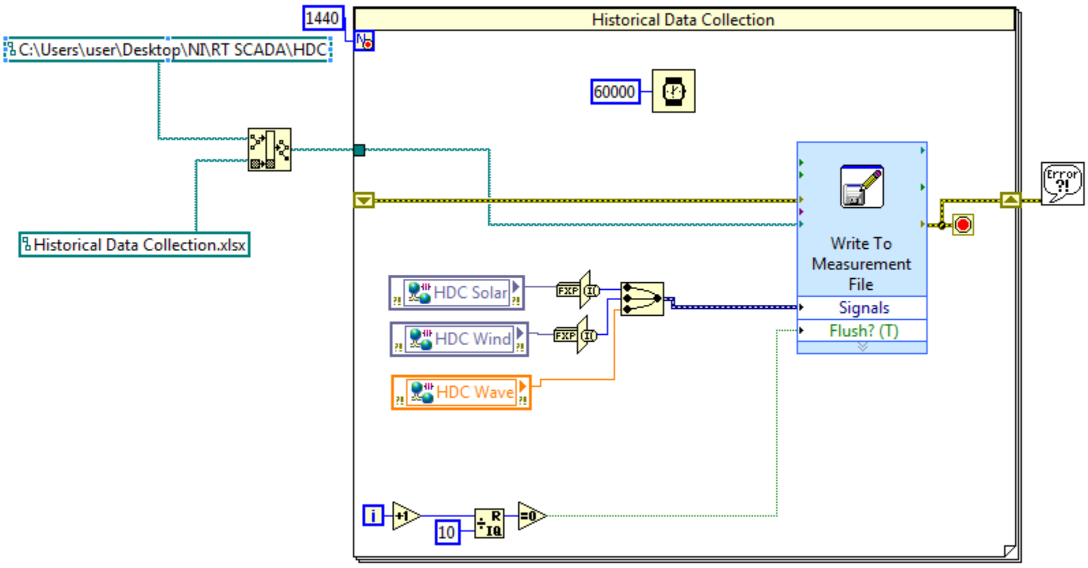
The arrangement of the myRIO-1900 hardware connection



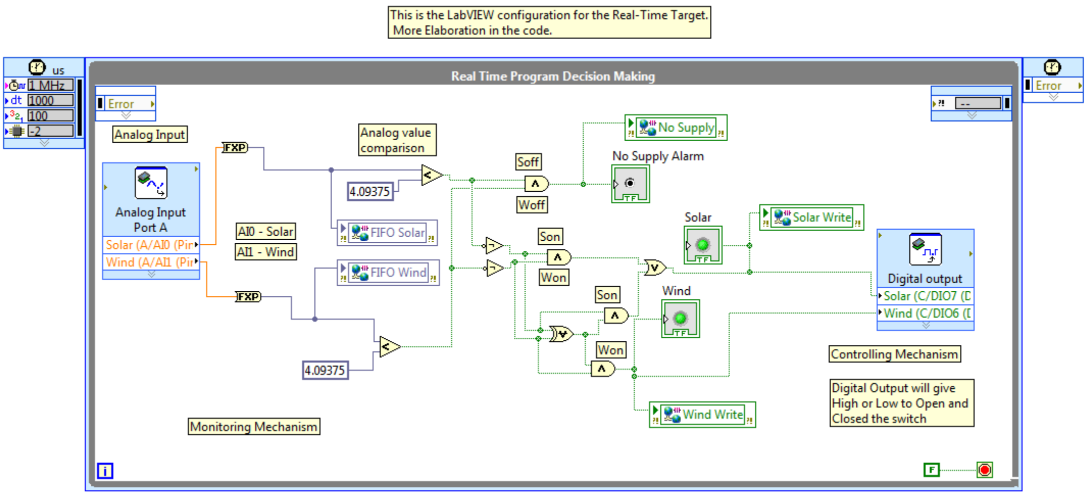
Appendix 4

LabVIEW Configuration Code





Historical Data Collection
1440
C:\Users\user\Desktop\NI\RT SCADA\HDC
Historical Data Collection.xlsx
60000
Write To Measurement File
Signals
Flush? (T)
HDC Solar
HDC Wind
HDC Wave
10



This is the LabVIEW configuration for the Real-Time Target. More Elaboration in the code.
Real Time Program Decision Making
Analog Input
Analog value comparison
Analog Input Port A
AI0 - Solar
AI1 - Wind
FIFO Solar
FIFO Wind
4.09375
4.09375
Soff
Woff
No Supply
No Supply Alarm
Son
Won
Solar
Wind
Solar Write
Wind Write
Digital output
Controlling Mechanism
Digital Output will give High or Low to Open and Closed the switch
Monitoring Mechanism