Power Line Control and Monitoring Using FPGA

Usama Bin Rehan[1], Asif Gulraiz[2*], Khyzer Amin[3], Shayaan Amin[4], Musa Raza[5]

[1] Student, Department of Electrical Engineering, Usman Institute of Technology, Karachi, Pakistan (usama1rehan@gmail.com)
[2] Department of Electrical Engineering , DHA Suffa University, Karachi, Pakistan (asifgulraiz2002@hotmail.com) * Corresponding author
[3] Student, Department of Electrical Engineering, Usman Institute of Technology, Karachi, Pakistan (aminkhizar@gmail.com)
[4] Student, Department of Electrical Engineering, Usman Institute of Technology, Karachi, Pakistan (shayyanamin@gmail.com)
[5] Student, Department of Electrical Engineering, Usman Institute of Technology, Karachi, Pakistan (musa.raza95@yahoo.com)

Abstract: It demonstrates practical monitoring and controlling of an electric transmission system as smart grid does in modern power systems. The proposed system consists of a main Grid station and four Substations. Contactors are used for switching and are controlled via FPGA (Basys-3). The FPGA controls all operations in the system like monitoring and controlling of all four substations and also the supply of electricity to its desired load. Current is taken as the primary parameter which is monitored on HMI through current transformers and all commands are executed considering its rating. Some salient features of this system are, load management, power distribution and centralized supervision, monitoring and controlling can be done from centralized control room.

Keywords: Current Transformers, Transmission Lines, FPGA and Smart Grid.

I. INTRODUCTION

Electricity is an important utility for this modern world so in order to keep its quality and reliability high we have to design such power distribution system which can enable the supply of power at worst conditions also [1]. The life of transformer decreases if they get overloaded, which results in power failure and cause difficulties for the number of users. Overloading is the main cause of failure in the distribution system.

Nowadays monitoring is generally done manually where a designated person visits physically to the substation and record the major parameters [2]. This type of monitoring cannot provide real time results for the occasional overloads and faults in the transformers since person has to visit the place physically. Solution of such problem is our proposed system which is based on online monitoring of important parameters which may save the asset and make it operational for longer period. This paper will identify the problem before any mishap. It has also the advantage of cost saving and greater reliability.

II. LITERATURE REVIEW

In current power market, a high pressure is on utilities to provide cheap and reliable power to consumers. Power companies like National Grid in USA and UK are anticipating a very competitive market place, they have to reduce the cost spend in maintenance with improved functionality of the electrical component. Reliable and less expensive power is the basic need of today's customers in order to fulfil this requirement a solution must be proposed because in past there is no concept of substation automation due to which many problems have been faced including cost, reliability and most importantly power [3]. A solution was proposed by [8] which uses PLC (Programmable Logic Controller) to automate the process of substations. Substation automation is defined as the integration of electrical equipment like transformers, relays, contactors etc. with a PLC in order to monitor their behaviour. Automated substations relies heavily on microprocessor-based equipment it could be circuit breakers or transformers or any other type of switch which are monitored by PLC and HMI will also provide a graphical interface [4] but PLC has limited range of inputs due to that reason large number of PLCs may be required to cover the whole area consist of many substations. Possible solution for this problem could be if PLCs can be replaced by FPGA since it has more number of inputs/outputs in comparison with PLC.

The system comprises of a main station as a grid, in addition there are four substations in order to work for different areas as load will be changed at different locations. It will take readings for all electrical parameters including current, voltage, power etc. so that with respect to measured data controlling can be possible for transformers through circuit breakers and contactors connected at variable loads.

Smart Grid is defined as an autonomous system which uses measured data in order to improve the efficiency of electrical distribution system [5] which makes an electrical system more reliable than the conventional one. In general SMART word can be abbreviated as:

- Specific
- Measureable
- Assignable
- Realistic
- Time Bound

Human Machine Interface is used to get GUI representation of the power system in which all parameters can be monitor and controlled.

As of now in Pakistan there is a major crisis of energy. Due to short fall of power there is an electricity shutdown for hours on a scheduled time in order to balance the load. The reason for this shortfall is not just because we are unable to produce enough energy it is also because of unevenly monitored distribution system. Smart Grid uses Smarter Technique to save energy it comprises of two words that are SMART and GRID. The word "GRID" refers to a normal electrical grid which provides electrical energy to its consumer whereas the word "SMART "refers to a technique to use the technology to its fully efficient way. Smart Grid provides a more efficient way to provide electricity. Following are the features by which Smart Grid saves energy.

- Use of Renewable Energies
- Two Way communication
- Smart Sensing
- Load Management
- Consumer Management
- Distribution Intelligence System
- Plug-in Electric Vehicles
- Energy Management on Consumer end.

III. METHODOLOGY

The system of figure 1 consist of following configuration.

- Power system can be managed and controlled from any remote location which can be anywhere.
- FPGA Basys 3 is used for monitoring and controlling of power system which is done through Human Machine Interface.
- FPGA Basys 3 is controlling the contactors and relays.
- FPGA Basys 3 is controlling the components in the substation.
- FPGA Basys 3 is controlling and switching in between all 4 substations.
- Communication between FPGA Basys 3 is done by Serial-to-USB cable through Human Machine Interface (HMI).
- In the block diagram shown below bold black lines are representing transmission lines, while other lines are used for controlling.
- Electrical path is formed from Grid Station to respective 4 substations then they go to the specific area as load which can be clearly seen in figure 1.

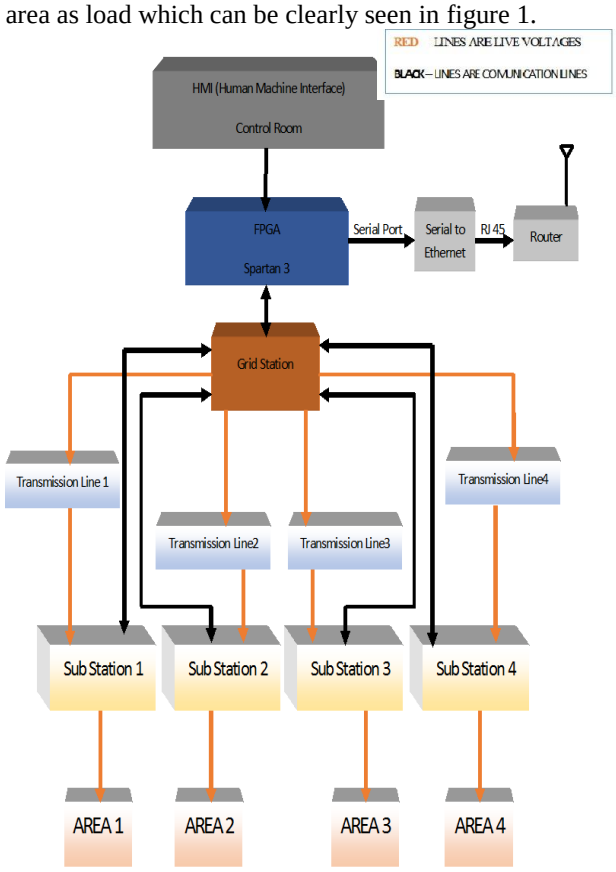

Fig. 1: Block Diagram

It consists of transformers, current transformers, ADC module, contactors, FPGA kit, triac circuit, relays and LCD display. Normally transformer fails to do its work properly due to overload and because of any short circuit in the line. Here to sense the fault we have used current transformers (CTs) [6]. This sensor is connected to converters ADC0804 and its digital output is connected to the address lines of FPGA kit [7]. LCD (HMI) will be connected to the address lines of FPGA kit. When any fault occurs it will be displayed on LCD (HMI) and immediate the alarm will ON and the process for desired side will go OFF. As we are interested in monitoring over current CT is being selected with suitable design with respect to desired condition of power system and rating of transformer.

The grid station will be the source of power. Grid station will provide power to further sub-stations equally. There would be a current transformer (CT) before each sub-station to monitor the current in the each particular

sub-station and area. The CT will provide indication to FPGA if the current is maximum the FPGA would shut down the load immediately. The FPGA will turn the sub-station OFF in case of any fault and overload condition and would isolate the particular sub-station through contactor logic. Now FPGA will check the nearest sub-station if it is capable for the power transfer to the sub-station which is OFF through the contactor logic. If once sub-station is not capable for that the FPGA will check the other sub-stations by using contactor logic.

All the faults and errors will be monitored and can be controlled from the control room which will comprise of HMI. Control room person would have all the rights to completely shut-down the operation and could isolate any individual sub-station for the maintenance. This whole process can be monitored from anywhere through internet.

Features of Smart Grid have been implemented which are as follows:

- During overloading due to any fault or malfunction in the substation load will be shut off and transferred to other substation.
- If any substation requires maintenance then the nearest substation can take up the load if it has a capacity as per its ratings so that consumer will not have any effect of it.
- If the load exceeds the pre-set values the substation will trip and automatically load will be transferred to the nearest substation.
- Current readings will be done via current transformer and will be continuously displayed on HMI.
- Manual switching of contactors and on/off of supply is also possible through HMI.

FIELD PROGRAMMABLE GATE ARRAYS (FPGA):

- Field Programmable Gate Arrays (FPGAs) are digital integrated circuit (ICs) that contain configurable (programmable) blocks of logics along with configurable interconnects between these blocks as shown in figure 1.
- Design engineers can configure such devices to perform remarkable variety of jobs.
- Reconfigurable hardware devices in which the functionality of the logic gates and their interconnections are customizable at run-time.

Fig. 2: FPGA Basys 3 Digilent board

CONTACTORS:

Contractor is defined as a type of switch which can be controlled electrically in order to use for switching purposes for electrical circuits, it has a similar function as relay with higher current ratings.
Contactors are used to control electric motors, lighting, heating, capacitor banks, thermal evaporators, and other electrical loads shown in figure 3.

Fig. 3: Contactors

HUMAN MACHINE INTERFACE (HMI):

As the name suggests, it is a human friendly machine used to interface Human with the machines running on the system. Input to the machines can be given through HMI and output can be displayed on it also.

Fig. 4: HMI DISPLAY

IV. PROPOSED FLOW CHART

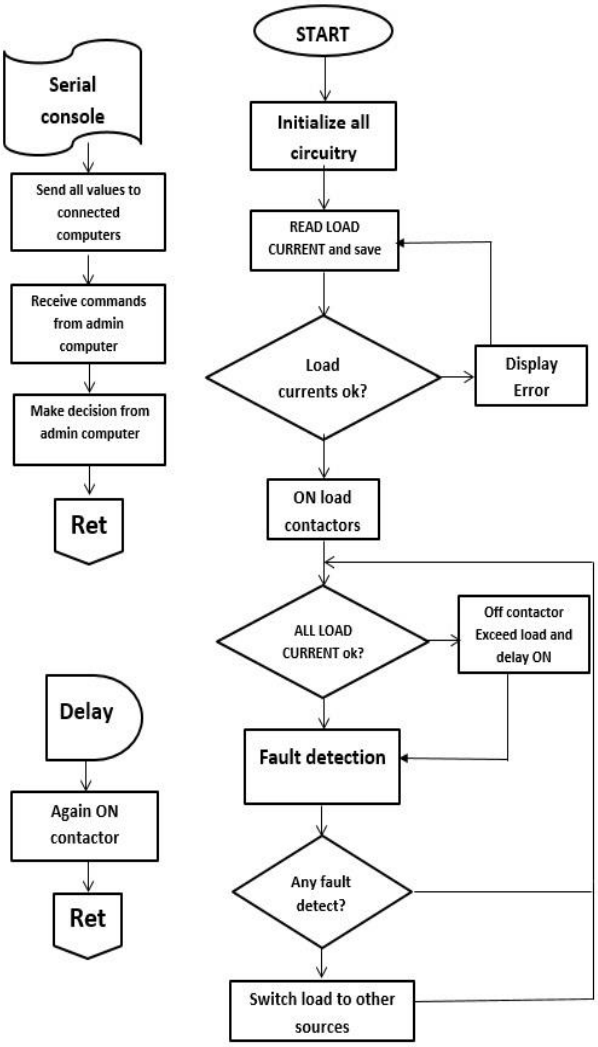

Fig. 5: Flow Diagram

V. WORKING

- Grid station operates all four substations.
- Grid station would have sufficient rights to completely shut down any substation keeping in view of load management.
- Control room will be made near to the grid station that can help the monitoring and control of each substation.
- Load management system can be improved day and night timing with the help of communication of grid station to substations.
- The FPGA controls and monitors all the operations of the project.
- The grid will comprise of ten contactors, each for a substation and a transformer, and other for shifting power.
- FPGA will be connected directly to the sub stations.
- The FPGA will communicate with the sub stations through flexible wire. But it can also have wireless monitoring with the project by adding an Ethernet module.
- Basically, FPGA is controlling and monitoring the switching of contactors of the substations and the relays of the load as well.
- If a substation fails or goes into maintenance, area won't suffer the consequences as a nearby substation will take over the load.
- When the nearby substation takes load, the remaining power will be given to the particular substation.

V. CONCLUSION

This paper introduces a smart monitoring system for a substations [6] as smart grid offers nowadays but still it is not a complete smart grid system but part of power line monitoring has been automated. Online monitoring improves service reliability and reduces outage duration and time [8]. Dedicated sub-station is centrally controlled through FPGA kit hence; data will be available on demand. Immediate alarm if the load exceeds preset values and shutdown command can also be preceded on demand. There is an automatic fault detection system and if any fault occurs the load will shift to any other sub-station.

Since the proposed system is designed for a maximum load of 1.5A, if the load exceeds from this value the system will trip and the information will be conveyed to the operator through FPGA kit on LCD (HMI) and FPGA kit will diagnose the problem and try to resolve it.

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