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Generation of Electricity by Renewable Energy Sources & Transmission of Energy Production Units using PLC & SCADA

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ABSTRACT-

Automation means Delegation of human control to machine. A PLC (Programmable Logic Controller) is a device that was invented to replace the necessary sequential relay circuits for machine control. A SCADA (Supervisory Control & Data Acquisition System) is used to control the process where person cannot go or stay for longer period. The aim of tis paper is to provide information about hoelectricity can be generated from Renewable sources & how its transmission done usin automation system. Renewable Energy consists of energy generated from natural and unlimited sources, which include wind, solar, biomass and hydroelectricity. Programmable logic controllers (PLC) can be used for control & automation in Distribution of Energy. The main reason for this is cost effectiveness. Various functions and controls can be achieved by programming the PLC. They can be used for full plant automation including governing of auto-operation includes speed control, load control, excitation control, and level control automatic start/stop sequencing, gate control, start/stop of auxiliary systems, and protection requirement etc. Functions other than control like continuous monitoring, data recording, instrumentation and protections can also be performed. For remote operation, communication with PLC can be performed. For continuous monitoring purpose, a personal computer can be interfaced with PLC and continuous data can be recorded regularly.
In this paper I used different methods for generation of electricity like wind, PV (photovoltaic), hydro, biogas & distributed using PLC & controlling using SCADA.

Key Terms- PLC (programmable Logic Controller), SCADA (Supervisory Control & Data Acquisition System), PV (Photovoltaic).

I. INTRODUCTION

The major renewable are hydro, solar, wind and biomass. The beauty of these renewable energy systems is that they are non-exhaustible.

A. Hydropower Generation-

The use of PLC in ***Hydropower*** Generation makes it easier for handling. In this work, a programmable logic controller is used as an industrial computer playing the role of a control device and push buttons, level and flow sensors provide incoming signals to the control unit. The PLC [1] is connected to the SCADA (Supervisory Control And Data Acquisition) which monitors the process. In the mid-1700s, French engineer *Bernard Forest de Bélidor* published *Architecture Hydraulique* which described vertical- and horizontal-axis hydraulic machines. In 19th century, the electrical generator was developed and could now be coupled with hydraulics. The growing demand for the Industrial Revolution would drive development as well.

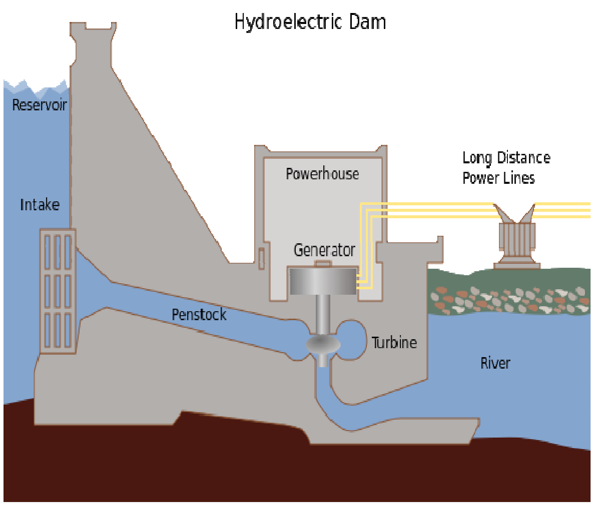

Fig 1- Power Generation using Hydroelectric dam (PLC based) [Google Image Wikipedia]

B. Wind Power Generation-

A wind farm is a group of wind turbines in the same location used for production of electricity. A large wind farm may consist of several hundred individual wind turbines, and cover an extended area of hundreds of square miles, but the land between the turbines may be used for agricultural or other purposes. A wind farm may also be located offshore.
In the American midwest between 1850 and 1900, a large number of small windmills, perhaps six million, were installed on farms to operate irrigation pumps. Firms such as Star, Eclipse, Fairbanks-Morse and Aeromotor became famed suppliers in North and South America. By late 2011, Japan announced plans to build a multiple-unit floating wind farm, with six 2-megawatt turbines, off the Fukushima coast of northeast Japan where the 2011 tsunami and nuclear disaster has created a scarcity of electric power[2].

Fig-2 Wind farm for Generation of Electricity

C. Solar (PV) Generation-

Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. Solar panels produce direct current (DC) electricity, so solar parks need to conversion equipment to convert this to alternating current (AC), which is the form transmitted by the electricity grid. This conversion is done by inverters. To maximize their efficiency, solar power plants also incorporate maximum power point trackers, either within the inverters or as separate units. These devices keep each solar array string close to its peak power point. There will be losses between the DC output of the solar modules and the AC power delivered to the grid, due to a wide range of factors such as light absorption losses, mismatch, cable voltage drop, conversion efficiencies, and other parasitic losses. A parameter called the 'performance ratio' [3] has been developed to evaluate the total value of these losses. The performance ratio gives a measure of the output AC power delivered as a proportion of the total DC power which the solar modules should be able to deliver under the ambient climatic conditions. In modern solar parks the performance ratio is 80%

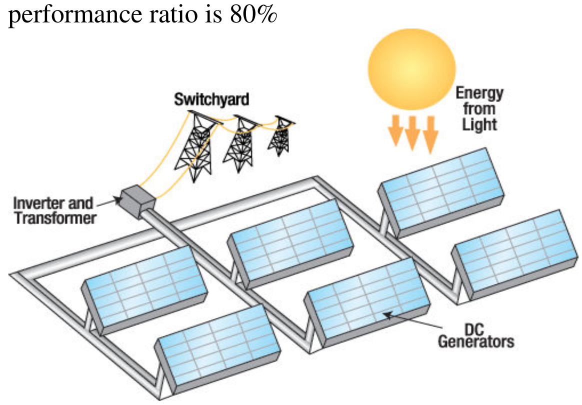

Fig-3 Power Generation using photovoltaic

D. Biomass Power Generation-

Biomass, as a renewable energy source, is biological material from living, or recently living organisms. [4] Enough Biomass resources in the world to cover the world's
energy demand.[5]As an energy source, biomass can either be used directly, or converted into other energy products such as biofuel. Thermal conversion processes use heat as the dominant mechanism to convert biomass into another chemical form. The basic alternatives of combustion, torrefaction, pyrolysis, and gasification are separated principally by the extent to which the chemical reactions involved are allowed to proceed (mainly controlled by the availability of oxygen and conversion temperature).

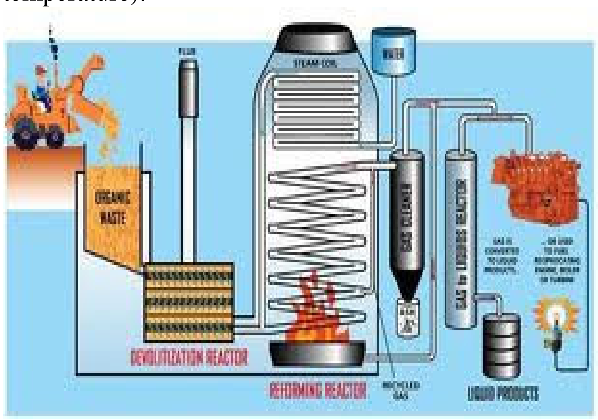

Fig 4- Generation of power using Biomass process.

2. TRANSMISSION STRUCTURE OF GENERATED POWER-

A **Renewable energy power station** is a broad term relating to power stations that generate electricity in a centralised manner from sustainable sources such as solar, wind, water, biomass or geothermal which is then supplied to a public grid for consumption.

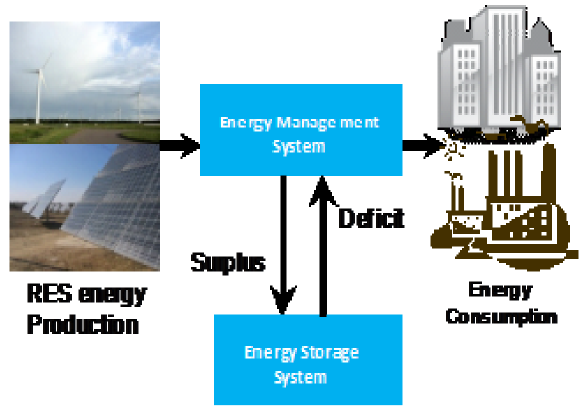

Fig 5- RES energy Production & ESS [15]

RES- Renewable Energy Sources
ESS- Energy Storage System

As shown in fig 5 shows basic dia for Generation, storage & Distribution System. Power Generated by various Renewable Energy Sources is stored in various storage devices like batteries, Advance Sodium-Sulpher batteries etc. & then transmitted in different sectors for use.

Fig 6- showing different Renewable Energy Generation & then collected in batteries. If generated power is in AC form firstly converted it into DC & then stored or transferred. But transmission loss of DC power is more so we convert it into AC by DC to AC converters.

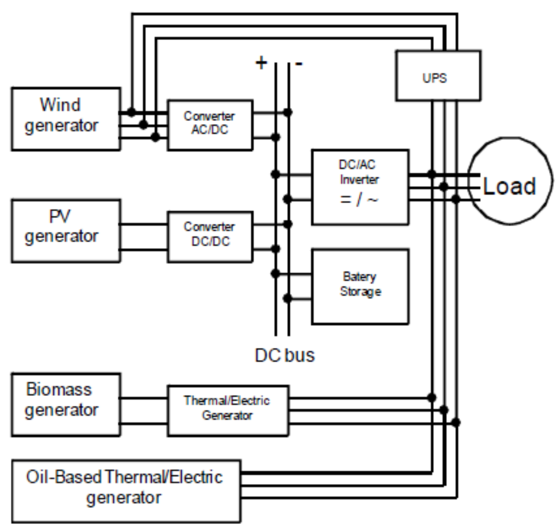

Fig 6- Electrical schematics of multiple power generation [15].

As shown in fig-6 Renewable Energy Sources generates power & then it stored in batteries, Sodium sulpher batteries etc.

A. Transmission of Power generated by Winfarm-

All Generators connecting to the Transmission System are required to comply with the Grid Code. The Grid Code was originally developed with synchronous generators in mind. Since Wind Turbine Generators (WTG) do not have the same characteristics as synchronous generators, it was considered appropriate to develop a new set of Grid Code provisions specifically for Wind Farm Power Stations. This section of the Grid Code is intended to refer specifically to Wind Farm Power Stations.

Wind Farm Power Stations shall remain continuously connected to the Transmission System at maximum Available Active Power or Curtailed Active Power output for the following normal Transmission System Voltage ranges:

(a) 400kV system: 370kV to 410kV;
(b) 220kV system: 210kV to 240kV;
(c) 110kV system: 105kV to 120kV.

If wind energy is there then AC to DC converter is used to convert AC power to DC for storage per purpose. Again for Distribution purpose DC power is again transferred to Ac for further use. Wind Generator generates AC power so we have to convert it into DC & hence we use AC to DC converter.

B. Transmission of Power Generated by Hydro System-

A simple formula for approximating electric power production at a hydroelectric plant is:

$$P = \rho hrdk$$

where

P is Power in watts,

ρ is the density of water (~1000 kg/m^3),

h is height in meters,

r is flow rate in cubic meters per second,

g is acceleration due to gravity of 9.8 m/s^2,

k is a coefficient of efficiency ranging from 0 to 1. Efficiency is often higher (that is, closer to 1) with larger and more modern turbines.

Emera and Nalcor will form a joint venture to construct transmission facilities from Labrador to Newfoundland at a cost of $2.1 billion.

The Labrador-Island Transmission Link will be a 900MW 1,100 KM High-voltage direct current (HVDC) bipole from the Muskrat Falls switchyard in central Labrador to an area near Soldiers Pond on the Avalon Peninsula [6].This work will result in at least one million person hours of engineering and project management employment and 2.5 million person hours of construction employment in the province.

Key components include the following:

i) 345kV AC to 320kV DC Converter station at Muskrat Falls. [6]

ii) An overhead, two-conductor HVDC transmission line from Muskrat Falls to the Strait of Belle Isle [6]

iii) Three mass-impregnated, sub-sea cables crossing the Strait of Belle Isle with associated infrastructure [6]

iv) An overhead, two-conductor HVDC transmission line from the Strait of Belle Isle to the Avalon Peninsula [6]

v) 320kV DC to 230Kv AC Converter station at Soldiers Pond.

C. Transmission of Power Generated by Photovoltaic-

1) Solar Cells-

The first step in turning sunlight into grid power is the solar cell. Solar cells convert sunlight into electricity through a process where light energy in the form of a photon strikes the solar cell, creating a small amount of electricity. Groups of these cells make up a panel, which is rated by the number of watts of electricity the panel can generate per hour under optimum conditions for the cell. Panels can also be grouped together into modules, which can contain the inverter as well as the solar panels.[7]

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2) The Inverter-

This energy generated by the panel, in the form of direct current (DC), is transmitted to the inverter. The job of the inverter is to convert the DC power the solar panel has generated to alternating current (AC) that is transmitted on the grid. The reason the grid uses AC rather than DC is that DC power can't be transmitted over long distances without significant power loss. AC power can be transmitted over hundreds of miles with minimal power loss, making it perfect for an electrical distribution system.

3) PV Systems-

Two types of PV systems are grid-connected systems and stand- alone systems. The main difference between these systems is that one is connected to the utility grid and the other is not.

i) Grid-Connected Systems-

Grid-connected systems are designed to operate in parallel with, and interconnected with, the national electric utility grid. What is the grid? It is the network of cables through which electricity is transported from power stations to homes, schools, and other places. A grid-connected system is linked to this network of power lines. The primary component of a grid-connected system is the inverter, or power conditioning unit (PCU). The inverter converts the DC power produced by the PV system into AC power, consistent with the voltage and power quality requirements of the utility grid. This means that it can deliver the electricity it produces into the electricity network and draw it down when needed; therefore, no battery or other storage is needed.

The following picture is from California 2-MW grid connection system. The difference between Grid-Connected System & Stand Alone System is energy storage system & conversion of energy.

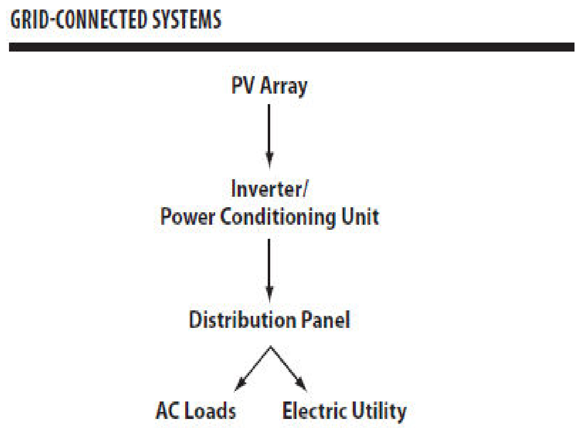

Image courtesy of PG&E

PG&E's Vaca-Dixon Solar Station in California is a 2-MW grid-connected system.

Fig-7 Grid-Connected System

ii) Stand-Alone Systems-

As its name suggests, this type of PV system is a separate electricity supply system. A stand-alone system is designed to operate independent of the national electric utility grid, and to supply electricity to a single system. Usually a stand-alone system includes one or more batteries to store the electricity. Historically, PV systems were used only as stand–alone systems in remote areas where there was no other electricity supply. Today, stand-alone systems are used for water pumping, highway lighting, weather stations, remote homes, and other uses away from power lines.

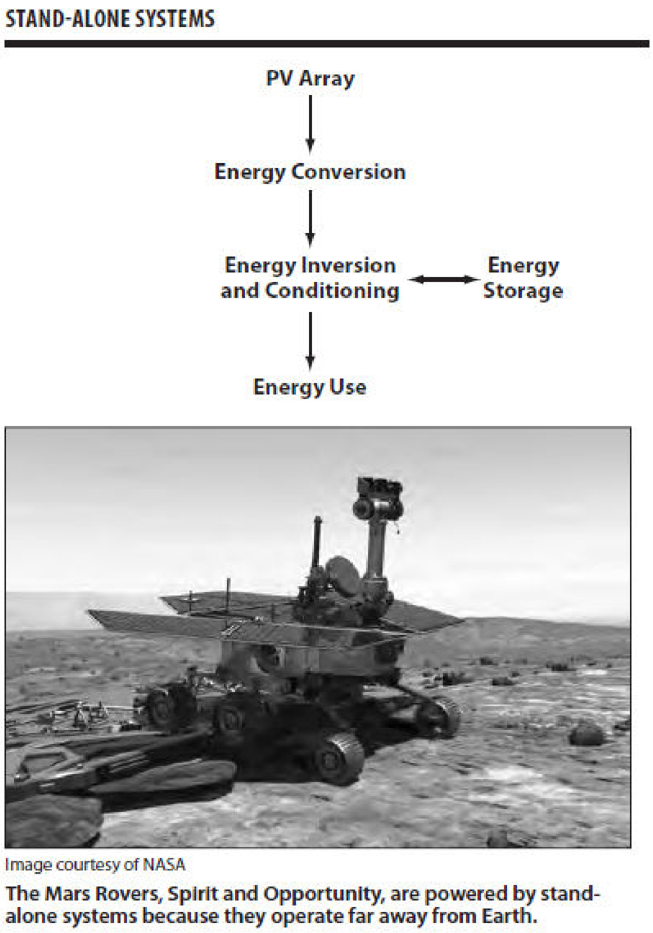

Fig-8 Stand-Alone System

D. Transmission of Power Generated by Biomasss-

Energy transmission is the process of moving electrical energy or a gas or liquid energy source (such as oil or natural gas) from its point of generation or extraction to its point of distribution or consumption. Electrical energy is transmitted via transmission lines, while liquids and gases are transmitted through pipelines. There are two major types of transmission lines: alternating current (AC) and direct current (DC). However, they have a variety of voltages (generally between 115 and 765 kV) and configurations.

There are three major types of pipelines used to transport hydrocarbons: crude oil, natural gas, and product pipelines. There are three components of a natural gas pipeline system: the gathering system, the interstate pipeline, and the distribution system.

Although the information presented in this section is based on the attributes of crude oil pipelines and interstate natural gas pipelines, in general terms, the information about impacts and mitigation measures would be applicable to any type of pipeline. [8]

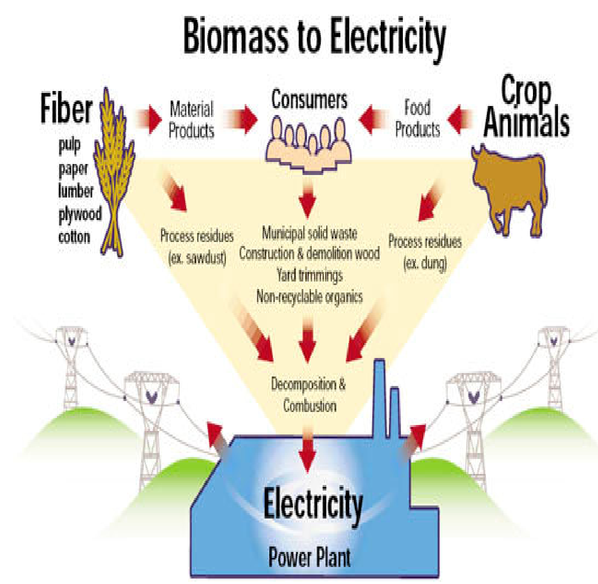

Fig-9 Production of Electricity by Biomass.

3. SYSTEM CONTROL USING PLC & SCADA-

PLC is used for centralized management. It is a Master PLC. Many Slave PLCs are connected to Master PLC. SCADA is used for outer loop management.

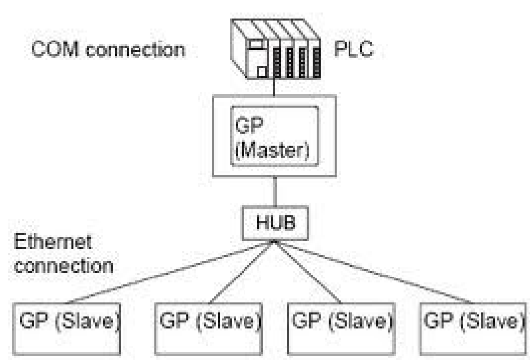

Fig-10 Master-Slave PLC system

In each power unit there exists a slave PLC, which is connected to the master PLC through a Profibus network. This power unit PLC monitors and controls the on-line power delivery to the electric grid. Similarly each ESS has a slave PLC controlling the income/outcome energy in the system. Each PLC hosts several control programs whose selection is made either locally, via an HMI (Human Machine Interface) or remotely, via the Master PLC. The Master PLC is connected to the server PC, via RS232/ MPI Siemens protocol, where the SCADA application is running.The server PC is simultaneous a SCADA server and an internet server, as the implemented SCADA application is web enabled. All process variables are available at the SCADA PC as these variables are on-line available through a Profibus/ DP connection protocol (Siemens,2001a).

Fig 10-shows the four slave PLCs for windfarm, PV, Hydro & Biomass respectively. A Supervisory Control and Data Acquisition (SCADA) System is used as an applicationdevelopment tool that enables system integrators to create sophisticated supervisory and control applications for a variety of technological domains, mainly in the industry field. The main feature of a SCADA system is its ability to communicate with control equipment in the field, through the PLC network. As the equipment is monitored and data is recorded, a SCADA application responds according to system logic requirements or operator requests. In the developed control strategy, the SCADA application performs the outer control loop ofthe energy plant system. At this outer loop several complex control structures can be used to manage the overall system dynamics.[15]

Assuming that the projected hybrid power plant had been optimal designed (Shaahid & Elhadidy, 2008), the role of the platform here developed is basically to minimize the energy supplied by the oil-based back-up power units. We use the potential of the SCADA supervisory platform to integrate the monitoring of the real production figures on the optimization problem.

The proper electricity production to each power unit is presented below in below eqn [15].

$$\min J = \sum C_{PVi} Y_{PVi} + \sum C_{windj} + \sum C_{oillWoil}$$

where:

c_{PVi} = production cost associated with PV plant i;

y_{PVi} = requested Watt-power to be supplied by PV plant i;

c_{windi} = production cost associated with Wind plant i;

c_{oili} = production cost associated with oil-based thermal plant i;

The optimization algorithm implemented for the energy management, at the SCADA outer loop control, could not be implemented directly on the SCADA system, as this complex controller needs mathematical operations that are not present at usual available SCADA systems. In this paper we developed a strategy to couple the SCADA system with the MATLAB software (Mathworks, 2005). [13] The communication between SCADA and MATLAB was performed using the DDE protocol (Dynamic Data Exchange). This communication protocol, developed in the 90's but still very common, permits the exchange of data between two independent running software programs (Client and Server). [10]

4. SOFTWARE & HARDWARE REQUIREMENTS-

A. Software requirements-

The software used for the PLC programming was the Siemens Simatic Step 7 (Siemens, 2000). [9]The Scada system was developed over the platform Siemens WinCC (Siemens, 2005). [10][11]

B. Hardware requirements-

Figure 8 shows an overview of the implemented prototype. Referring hardware characteristics each PLC (Master and Slaves) was composed by the following Siemens modules:
Slot1 = Power supply PS 307-2A
Slot2 = Processor CPU 315-2DP
Slot4 = Communication module CP 342 -5
Slot5 = Digital card DI8/DO8xDC24V/0,5A
Slot6 = Digital card DI8/DO8xDC24V/0,5A
Slot7 = Analogue card AI4/ AO2x8/ 8bit

Additionally, the Master PLC has a modem for GSM communication that provides the system capacity to communicate through the mobile phone network. The sensors used to monitor the generated and consumed electric power/ current are a set of AC/DC current transducers, coupled to energy analysers, with Profibus communication. In our case the energy meters used were the family Siemens SIMEAS P.[12]

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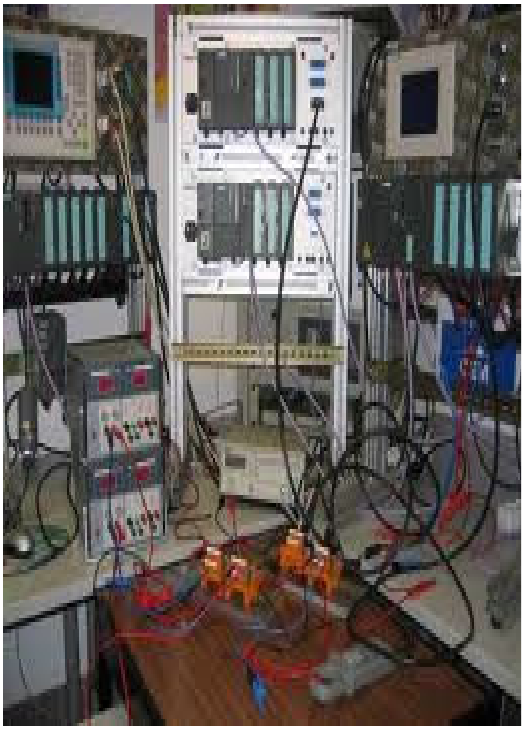

Fig-11 Experimental Setup to Test Energy Management System (EMS)

The power generation of the considered RES units, was simulated through 2 DC-power supplies, and 1 AC-Power supply, which simulated the power output from the DC converters and the AC-generator illustrated in fig 6. The power amplitude was externally changed.

5. RESULTS-

The SCADA system used to implement this monitoring and control strategy permits the selective access to the application, depending on the user's responsibility degree. In this paper we developed three user levels: Operators, Supervisors and Administrators. Several SCADA menus were built. The main characteristic of a SCADA Menu is to be simple, explicit and quick on transmitting the information to the operator or to the System Administrator.

Fig- 12 shows Graphical representation of completed Power Plant Production (PV unit, Biomass unit, Wind Unit & Consumption).The on-line available information, referring actual data from each power unit is: actual values and maximal daily values for Voltage, Current, Power and efficiency ratio (actual Value/max. Value).

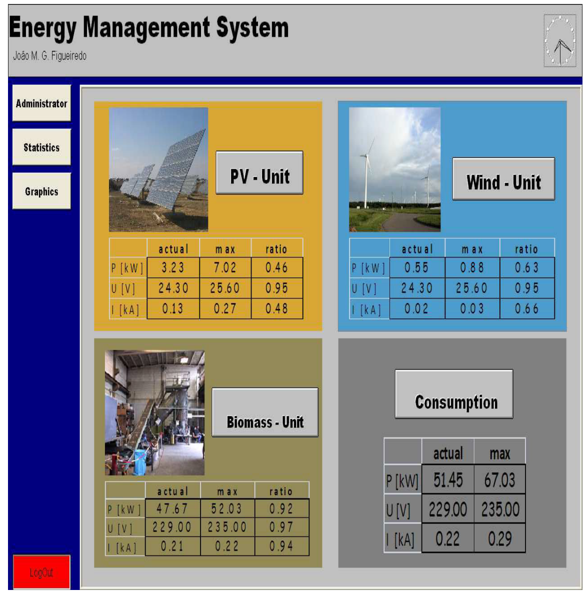

Fig-12 Complete power plant production [15]

6. CONCLUSION-

The Energy Management System in this paper consit of PLC for inner loop controlling & SCADA for outer loop controlling. PLC is centralized PLC having four slave PLC for different processes like wind energy, hydro power, photovoltaic & biomass respectively.

Due to Energy Management System using PLC & SCADA operational cost decreases & also easy to handle. Online monitoring & distribution of energy is possible due to this developed Energy Management System.

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