

# CEMENT PLANT SIMULATION AND DYNAMIC DATA COMMUNICATION USING NI LABVIEW AND MATRIKON OPC

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## ABSTRACT

This paper presents a cement plant simulator designed on LabVIEW platform. It generates process data and electrical parameters for all the lines of workshops in the cement industry. The simulated design is universal and applicable to all kinds of cement plants. Client-server architecture is established and the generated parameters are communicated to Matrikon OPC client. Single Line Diagram of the electrical distribution of cement plant has also been developed using MS Visio. An exclusive user interface has been designed to monitor and analyze the electrical parameters in detail. The KWh/tonne consumption and % energy consumed by the workshops have been observed and tabulated. Also, all the process and electrical data are exported to NI Citadel Database. So, in a single design, all the relevant key performance indicators (KPI's) for the process are calculated and displayed.

**Keywords:** *Process Data, Electrical Parameters, Kwh/Tonne Consumption, OPC, Client-Server, Single Line Diagram, KPI.*

## 1. INTRODUCTION

Cement is one of the most important constituent for construction of buildings. Cement provides the chemical bonds that hold the other materials together to form a dense rocklike substance. Since cement is one of the largest consumed materials, it has to be produced in huge amount. The production of cement is a highly energy intensive process. The cement industry consumes 2% of the world's total energy.

Various research works have been done and numerous papers and articles have been published on how to monitor and optimize the cement process plant. The paper [1] has proposed a new voltage distribution system which consists of a 69 kV high voltage system and 2400 V to 4160 V medium voltage system. It also explains that dry kiln process is far better than wet kiln process and separator should be installed in the Finish Mills to improve the capacity. In [2], a novel control algorithm has been developed to determine the proportion of the

raw mixture to be fed into the Raw Mill. It uses singular value decomposition for the calculation of the raw mixture proportion. In [3], several control and optimization applications are proposed to be implemented on the Finish Mills and Kiln. These control objectives aim at maximizing stability, production rate and efficiency. The article in [4] deals with the emerging trends in cement plant control systems. It explains how PLC's can be used as a replacement of the relay control systems and how the combination of PLC and DCS can be used to monitor and control various processes in the Cement plant effectively. The article also throws light on Plant Asset Management in which the control system includes mechanical equipment, computers, networking, drives, motors and process instrumentation.

In [5], a modeling approach has been designed for a two-chamber Ball Mill used in Finish grinder. The simulation determines the breakage rate and then adjustments are made in the ball size. This leads to capacity improvement and thereby reducing



overall specific energy consumption. The paper [6] has proposed a new design for Pyro-processing unit which reduces the carbon dioxide production. In the calciner stage, the  $\text{CaCO}_3$  and  $\text{MgCO}_3$  are decomposed to  $\text{CaO}$ ,  $\text{MgO}$  and  $\text{CO}_2$  without using any fuel and for this purpose, a hot stream of pure  $\text{CO}_2$  is used and again re-cycled.

In this paper, a monitoring system has been developed for the entire cement process plant on LabVIEW platform. The simulated design generates both process data as well as electrical parameters for different monitoring points. The electrical parameters can be monitored and analyzed in detail, for all the machines and equipments used in different workshops, in a specially designed user interface. These process and electrical parameters are also exported to a database, so the past data can be referred and analyzed. Another important feature of the design is that all the parameters are communicated to Matrikon OPC client with the help of client-server architecture. So, from the OPC, all the communicated data can further be passed to dashboards where the plant manager can view all the dynamically changing data in graphs and charts.

The design is completely automated and universal. All the initial inputs and specifications are loaded into the simulation from an Input Specification Excel file. So, the manufacturer of any plant can modify this file so that the design suits his plant.

Since the proposed design generates all the process and electrical data for all the workshops, it can be used further to study the various characteristics and optimize the process.

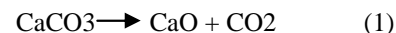
## 2. CEMENT PROCESS PLANT

### 2.1 Lines of Workshops

A typical Cement Industry has nine lines of workshops. There are six main lines namely Crusher (CR), Raw Mill Grinder (RMG), Fossil Fuel Grinder (FFG), Pyro-Processor (PP), Finish Grinder (FGR) and Packing (PCK). Also, there are three secondary workshops, Alternate Fuel Preparation (AFP), Utilities (UTL) and Non-Production (NP). Each of these workshops further comprises of different subparts and has its own set of inputs and outputs.

A Crusher is used to crush the raw materials obtained from quarries into smaller particles and is generally incorporated at both primary and secondary levels. Hence, they are called primary and secondary Crushers. The Raw Mill first mixes

the three inputs, limestone, clay and iron ore in appropriate proportion and then grinds the mixture to give fine powder which is stored in Raw Mill Silo. The Pyro-Processor unit comprises of Preheater, Kiln DC drive and Kiln Cooler. The finely divided mixture is then passed through Preheater where most of the de-carboxylation takes place and limestone is converted into quicklime with the liberation of carbon dioxide as shown in (1) below. The temperature is maintained at  $800^\circ\text{C}$ .



In the Kiln, the temperature range is  $1400\text{--}1500^\circ\text{C}$  and coal from the Fossil Fuel Grinder is used as the major fuel. Also, alternate fuels can be used from the Alternate Fuel Preparation unit. The output is called clinker which is then cooled in the Kiln Cooler section and stored in Clinker Silo. The Finish Grinder unit consists of a huge cement mill. The mill takes clinker, slag and gypsum as inputs and produces Portland Slag Cement [PSC] as the output. This cement is then sent to packing unit where the packing machine operates continuously to produce standard cement packets of 50 kg each. The Utilities unit consists of lighting, compressor and HVAC used in the production areas and Non-Production unit includes lighting and HVAC used in non-production areas.

### 2.2 Energy Distribution

The Cement Industry is said to be an energy-intensive industry together with steel, paper and petrochemical industries. The percentage of energy cost in Portland cement production cost is 20% to 30%. If the energy cost is reduced, the manufacturing cost is lowered, resulting in increasing the company's profits. In general, Cement process plant has nine lines of workshop as discussed in section 2.1.

Each workshop consumes different amount of energy depending on the motor rating of the machines and equipments used in the workshop. There are mainly two different forms of energy used in plant i.e. thermal energy and electrical energy. Finish Grinder consumes maximum amount of electrical energy. On the other hand, Pyroprocessor consumes huge amount of thermal energy as it extracts its energy from coal and other alternate fuels. Finish grinder consumes about 60% of the total electrical energy and Pyroprocessor consumes about 90% of the total thermal energy. There is another factor that affects the energy distribution i.e. the  $\text{CO}_2$  emissions. The electrical energy distribution and consumption are dealt with in this paper.

3. PROPOSED CEMENT PLANT DESIGN

3.1 Dynamic Simulation

The proposed architecture is a highly automated solution for Cement Process Plant. It has been developed on LabVIEW platform software version 2009. The simulated model generates real time process and electrical data and the design is very efficient and user friendly.

Different cement plants use various kinds of machines and equipments having different motor ratings and specifications. This has been taken into consideration while designing the architecture. There is an excel database in which all the input parameters and specifications have been pre-loaded and this file is used in the proposed simulated model. The operator can modify these specifications such as operational voltage, KW rating, tonnes of raw materials etc in the Excel file so that the design can resemble the actual plant. Thus, the proposed model is universal and modular.

The architecture has two main parts- Input configuration and Monitor process. So, first the

operator has to configure the inputs. It includes the type and loading factor of main drives of Crusher, Raw Mill Grinder, Fossil Fuel Grinder and Finish Grinder. Also, the operator has to mention the tonnes of cement output which he wants to manufacture.

The operator can monitor the entire plant in the Monitor process UI as shown in figure 1. It displays both the process data as well as the electrical parameters for each and every workshop. The design is completely dynamic and these parameters are updated every second. There are storage tanks in between different workshops. In order to avoid any overflow in these tanks, emergency pause controls are provided at the top right corner of the window. These pause controls can be configured at any point of time at the workshop level to halt that particular workshop. This may also be useful in any breakdown, short circuit or emergency condition in the workshop. There is a master stop control at the bottom right to stop the entire plant. Also, there is a status indicator LED at the top right corner which indicates the status of the plant.

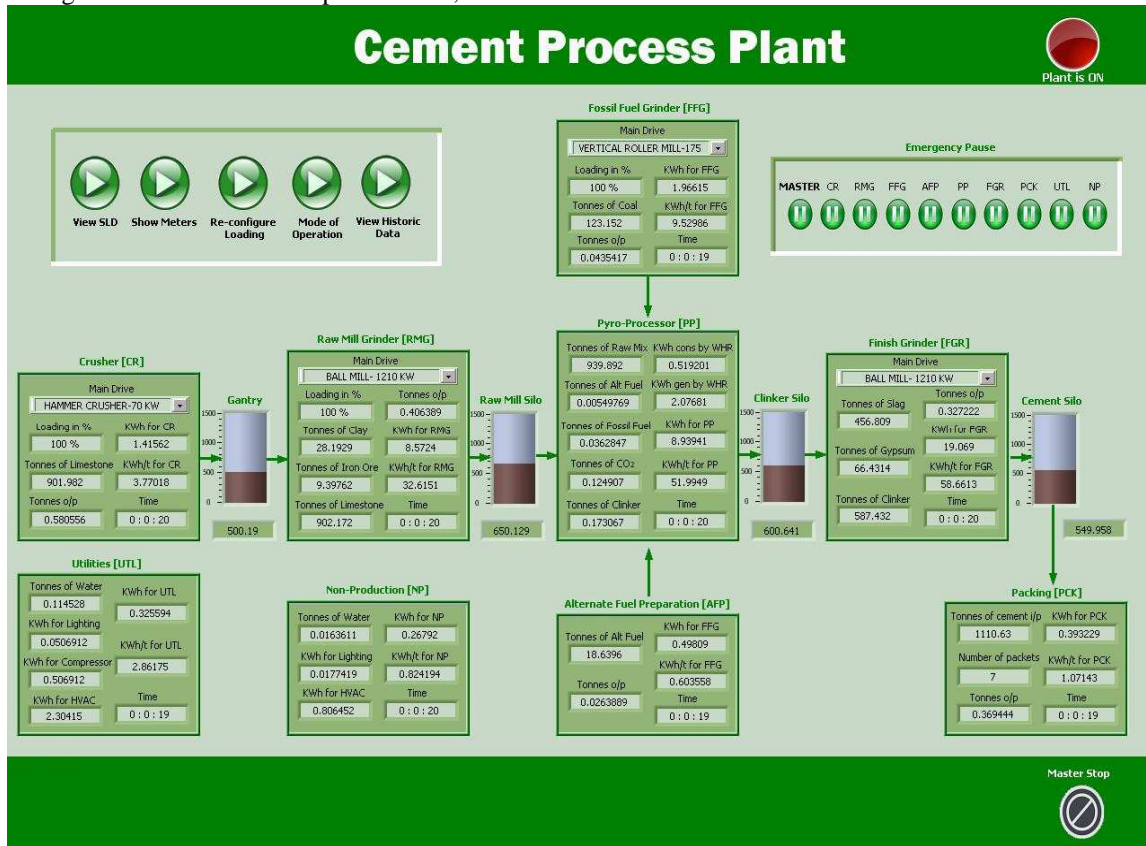


Figure 1 - Monitor Process UI

### 3.2 Single Line Distribution [SLD] Electrical Distribution

In the Monitor process window, the operator can use the View SLD control to open the SLD window. The Single Line Diagram [SLD] represents the electrical distribution of the entire Cement Plant. It is developed on Microsoft Visio software version 2007.

It has all the nine lines of workshops arranged in a systematic order as shown in figure 2. Each workshop comprises of various sub-parts like main drive, auxiliaries, etc. and these sub-parts are represented by motors in the SLD. Transformers are used to step down the voltage. The various operational voltages are 20 KV, 6.6 KV, 3.3 KV and 400 V.

There are three different kinds of meters in the SLD. Basic meter is used for all the machines,

equipments and sub-parts in the workshops. These meters will work at different operating voltages. Secondary meter is used at the workshop level. It is used to accumulate the values of all the parameters from the basic meters. Each workshop will have one secondary meter. Primary meter is the main meter of the cement process plant. It will accumulate the values of all the parameters from the secondary meters. Thus, the primary meter will display the total electrical energy consumed by the entire plant. There will be only one primary meter in the whole plant. In the SLD, the current values have been displayed near every meter.

The user can implement the circuit breakers used in the SLD window. When he uses any of the breakers, all the subsequent meters will get disconnected from the circuit and the current values for the affected meters will become zero.

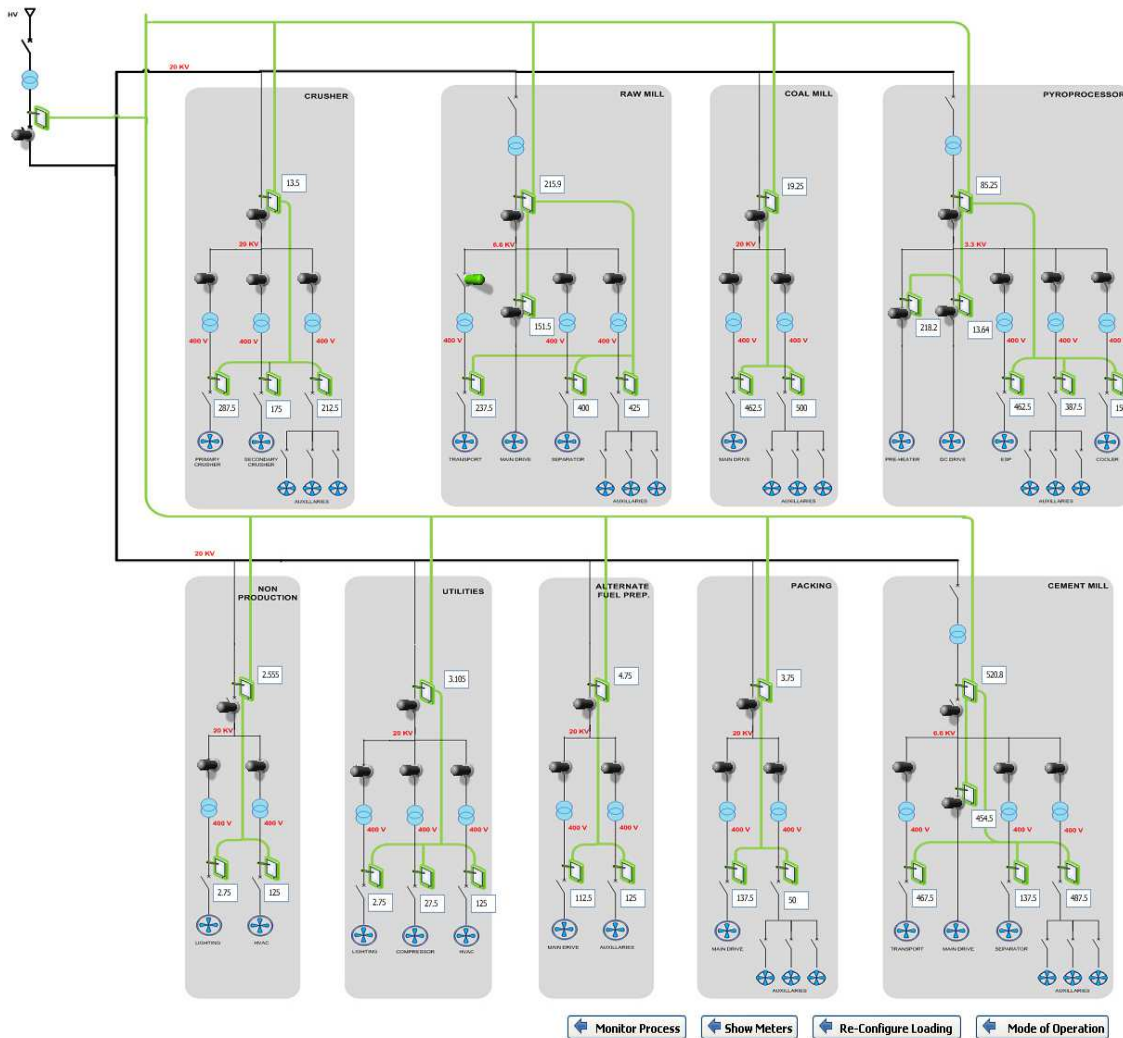


Figure 2 - SLD



### 3.3 Electrical Meters

This window is used for the detailed analysis of the electrical parameters for all the equipments used in the plant. When the operator clicks on the Show Meters control in the Monitor Process UI, a new window opens, as shown in figure 3. It has nine different tabs representing the nine workshops and each tab will have electrical meters for each sub-part.

The meter displays electrical parameters like current drawn, operational voltage, power in KW, energy in KWh and KWh/tonne consumption. Also, there is a manual on/off and reset control in each meter. The manual on/off can be used to switch off the meter such that the current and power values become zero and the energy and KWh/tonne values become stagnant. Further, the operator can use the reset control to reset all the values. When a circuit breaker is implemented in the SLD window, the effects are visible in the electrical meters.

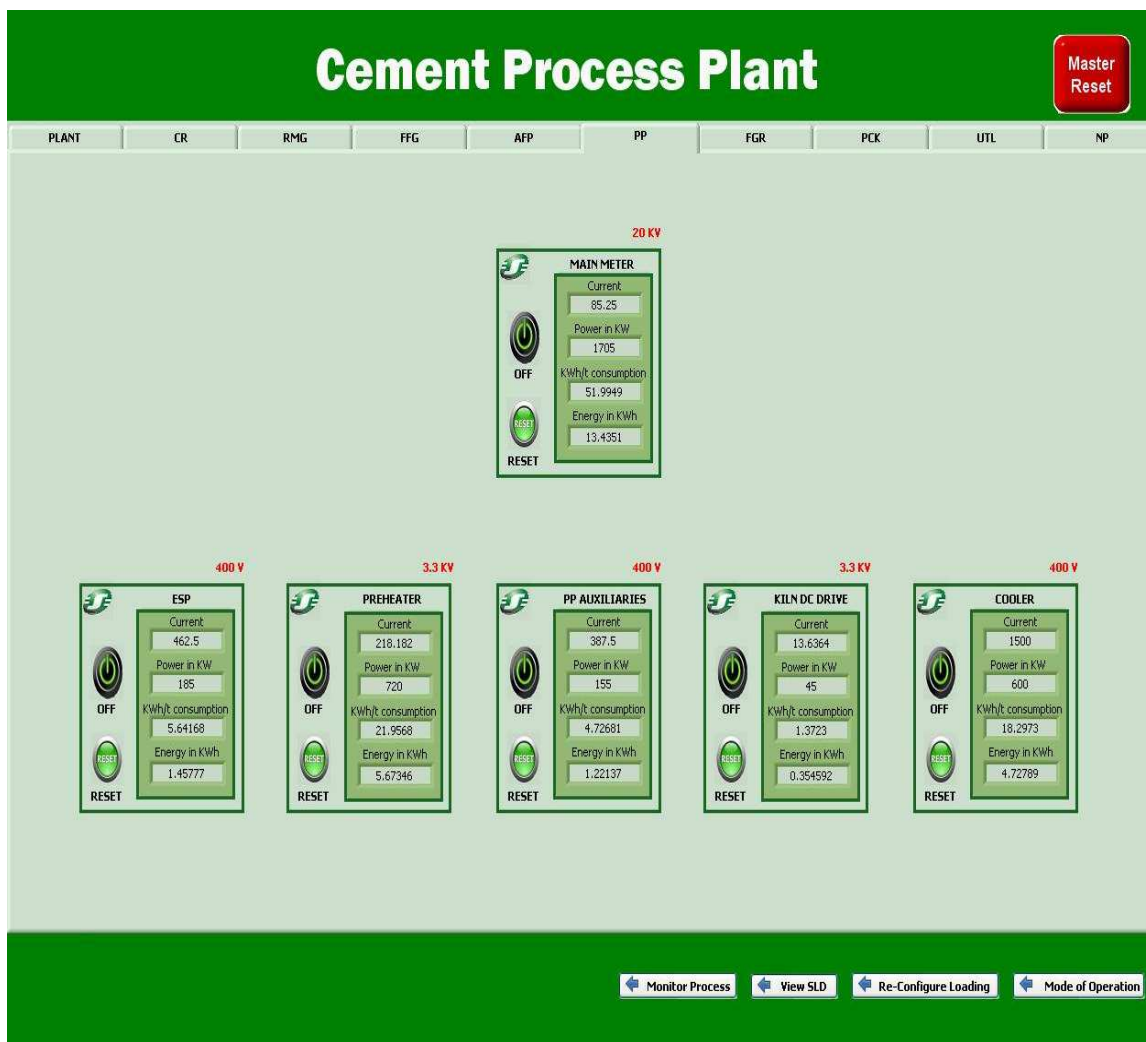


Figure 3 - Show MetersUI

### 3.4 Loading Factor and Mode of Operation

In the Monitor process window, the operator can use two more controls- Re-configure Loading and Mode of Operation. The Re-configure Loading control can be used to change the loading factor of the main drives of the Crusher, Raw Mill and Coal Mill. The operator can use the Mode of Operation control to change the mode at the plant level as well as at the workshop level. The plant can run in mainly two modes- normal mode and abnormal mode. By running it in abnormal mode, the manufacturer can estimate the adverse effects of any breakdown, short circuit or damage condition in the plant. Thus, this provides an additional feature to the operator to analyze the adverse effects in advance.

## 4. COMMUNICATING AND EXPORTING DYNAMIC DATA

### 4.1 Communicating Data

The shared variable concept in LabVIEW is used to read and write data across the network. The network-published shared variables are used in the design simulation and then deployed to a shared variable engine (SVE). This SVE hosts the shared variable values on the network as shown in figure 4. At the end of every second, the values of all the process data and electrical parameters get updated. These values are written to network-published shared variables and deployed to the SVE. The SVE records the changes in values and publishes the new values to all the subscribers. Matrikon OPC is used as a client and receives all the updated values issued by the SVE, which acts as a server.

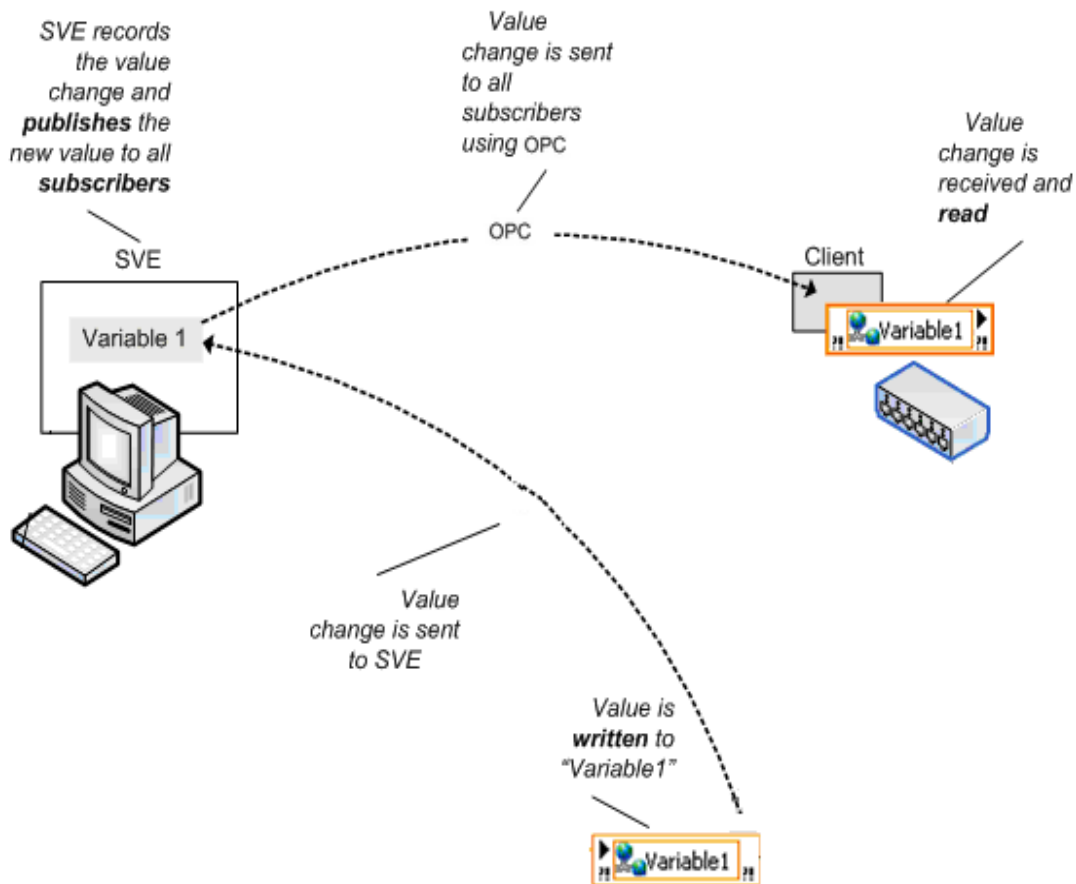


Figure 4 - Shared Variables Concept

**4.2 Exporting Data to a Database**

The LabVIEW DSC Module adds significant functionalities to network-published shared variables. With the help of DSC module, LabVIEW VI's can programmatically control all aspects of shared variables and the shared variable engine (SVE). When the View Historic Data control in the Monitor process UI, as shown in figure 1 is used, Measurement and Automation Explorer window will open. Then NI Citadel database can be used to view the values of all the shared variables graphically. The Citadel database also has an option to export these parameters to a file. Thus, past data can be recalled and analyzed at any point of time for any parameter.

**5. EXPERIMENTAL RESULTS**

The design simulator proposed in this paper can be used for analyzing both process data as well as electrical data. The process data includes amount

of inputs, TPH rating, amount of outputs etc for the nine lines of workshops present in the plant, while the electrical parameters include current, voltage, KW rating, energy in KWh and KWh/tonne consumption.

Table 1 shows the standard tonnes per hour (TPH) rating for all the major equipments used in the workshops. These TPH ratings can be modified by the user in the Input Specification Excel file. Table 2 shows the KWh/tonne consumption and % energy consumed by the workshops as a whole. These values are also standard but subject to change based on any modification in the Excel file. The % energy consumed by the workshops has been indicated in the pie chart as shown in figure 5.

*Table 1 - Process data: TPH rating*

WORKSHOP	TPH RATING
Crusher [CR]	110
Raw Mill [RMG]	77
Coal Mill [FFG]	8.25
Alternate Fuel Preparation [AFP]	5
Pyro-Processor [PP]	33
Cement mill [FGR]	62
Packing [PCK]	70
Utilities [UTL]	-
Non-Production [NP]	-

*Table 2 - Electrical parameters: KWh/t consumption and % Energy in KWh*

WORKSHOP	KWh/t consumption	% Energy in KWh
Crusher [CR]	3.77	1.7 %
Raw Mill [RMG]	32.62	14.9 %
Coal Mill [FFG]	9.78	4.5 %
Alternate Fuel Preparation [AFP]	0.60	0.3 %
Pyro-Processor [PP]	51.99	23.8 %
Total till Clinkerization	98.76	
Cement mill [FGR]	58.66	50.7 %
Packing [PCK]	1.07	0.9 %
Utilities [UTL]	2.86	2.5 %
Non-Production [NP]	0.82	0.7 %

\*TOTAL = (98.66 x 0.5289) + 58.66 + 1.07 + 2.86 + 0.82 = 115.59 KWh/t.

Here, 0.5289 is the amount of clinker used to produce one tonne of PSC cement.

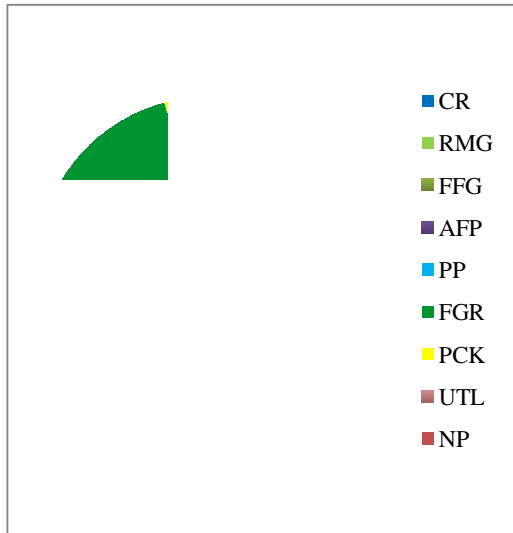


Figure 5 - Percentage energy consumed

## 6. CONCLUSION

In this work, we have developed a dynamic simulator for the Cement plant which generates both process and electrical data. These parameters are communicated through client-server architecture with the help of OPC. Also, all the data is exported to NI Citadel database. From this database, any data can be plotted graphically or exported to a file. Thus, it can be used as a good monitoring system. In the simulated design, all the process data for all the workshops and all the electrical parameters for all the machines and equipments are generated. Thus, a plant manager can easily monitor and analyze the entire plant and develop strategies to optimize the plant.

Since LabVIEW is used, the graphical programming is very advantageous. The UI's are very user friendly. The designing and coding are very easy to understand and modify. Debugging is less complex and less time consuming.

Another significant feature of the design is that it is universal and applicable to all kinds of Cement plants. The manufacturer of any plant can modify the specifications of the machines and equipments in the Input Specification Excel file so that the designed model resembles his plant.

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