# Design of Manufacturing Execution System for FMCG Industries

Arindam Banerjee[1] , Naveen Bommu[2] , Prateek Agarwal[3], Prof. N. Jaisankar[4]
1,2,3,4 School of Computing Science and Engineering, VIT University, Vellore -632014, Tamilnadu, India
[1]arindam.banerjee2012@vit.ac.in
[2]bommunaga.2012@vit.ac.in
[3]prateek.agrawal2012@vit.ac.in
[4]njaisankar@vit.ac.in

***Abstract*- Manufacturing Execution System (MES) has been evolved as an effective solution for today's high performance, mass production industrial automation system. MES acts like a bridge between managerial level ERP solution and shop floor level control systems hardwares. MES solutions are highly flexible which are developed and customized targeting some particular industry. In this paper we plan to design an MES architecture aiming FMCG (Fast Moving Consumer Goods) industries. The proposed solution keeps the basic MES architecture intact while improves production data capturing process based on batch event detection approach. It also accelerates the 2-way communication between ERP and MES for exchanging batch production data.**

**Keywords- MES, ERP, FMCG, Control System.**

## I. INTRODUCTION

Usage of computers in industrial automation for capturing real time data accurately and thus reducing manpower dates back in 1960's. As stated by Nonaka et al. [1], in this era of knowledge based economy, knowledge would take place of the traditional factors related to production and become the most important among all resources. Hence capturing knowledge in the form of data plays a crucial role in the success of any field of industry. Enterprise must be advanced enough in capturing vital data, analyzing and extracting knowledge out of captured data, incorporating new knowledge based decision for process and quality improvement, replacing out of date technology and adopting state-of-the-art, latest technological applications. Manufacturing Execution System (MES) thus evolved as a helping tool for manufacturing industries to capture data and extract knowledge in the form of decision. As the amount of real time data in manufacturing industries are huge and always available in very raw format from control systems, it had always been a tedious job to capture data accurately with high frequency before MES came. MES is a computerized automation system that can be operated in real time to control several manufacturing systems across the enterprise, capturing real time data, viewing and analysing data pattern for making decisions, quality control, report generation etc. MES also works as an intermediate level [16] between enterprise level Enterprise Resource Planning (ERP) system and floor level control systems as shown in fig: 1.

| | |
|---|---|
| **ERP** | **>> Production Planning**<br>**>> Human Resource Management**<br>**>> Sales and Purchase Management**<br>**>> Finance Management** |
| **MES** | **>> Resource Management**<br>**>> Real time data acquisition**<br>**>> Production flow control**<br>**>> Raw materials flow control**<br>**>> Production Scheduling**<br>**>> Production tracking and analysis**<br>**>> Quality Analysis Management**<br>**>> Maintenance Management**<br>**>> Line Efficiency Management**<br>**>> Access Management**<br>**>> Report generation**<br>**>> Control of remote users** |
| **Control System** | **>> Process monitoring and hardware control**<br>**>> Safety and Maintenance**<br>**>> Raw data flow control and supervision** |

Fig1. Three-layered model for enterprise integration

The reason of success of MES application in industrial automation is due to its flexible and easily customizable structure with powerful functions [15]. Also it is a significant research area to work on customization of MES for cost reduction and implementation of MES in many small and medium scale enterprises (SMEs) [17]. As a part of this research work, we will propose MES architecture purely based upon FMCG (Fast Moving Consumer Goods) industries.

The organisation of paper is as follows: first section I of basic *Introduction* is followed by literature study on *Related Work* which provides a comprehensive view of different existing MES solution models. Thereafter section III, *MES Overview*, elucidates design and architecture of MES technology in general. Section IV briefly discusses about *Events Definition* in MES solution. Further, section V describes *MES Reconfigurable Framework* which holds an extremely flexible and customizable structure for industry oriented application. Section VI covers the *Proposed Solution* followed *by Implementation Details* and result analysis insight into the work in section VII. Finally *Conclusion* section provides conclusions to the paper and proposes some future work.

## II. RELATED WORK

Several research activities on MES based upon different industries and platforms have been carried out to produce flexible and customizable architecture. Though the applications are industry oriented but the basic ideology remains same. Sheng-Luen Chung et al. [2] proposed a detailed design of MES solution aiming Semiconductor industry. The architecture consists of MES database (a relational database), MES transactions and MES Web server for remote clients. Another design by R. S. Chen et al. [3], also for semiconductor industries, integrated MES with OLAP (Online Analytical Processing) and Data ware housing for capturing, processing and analyzing huge amount of real time manufacturing data. Ruey-Shun Chen et al. also integrated MES, OLAP and data warehousing in their MES design [4] for semiconductor industry that provides a three tiered web based systematic framework. An MES implementation in cement manufacturing industry was proposed by Wen-qian Cao et al. [5] where UML concept was introduced in combination with quality management system in cement industries and modelling process. Implementation of MES in aerospace modelling enterprises was discussed in the research paper written by Muhammad Younus et al [6]. This design aims aerospace modelling industries – its complex manufacturing process and functions of modules. Wang Shewei et al. [7] also proposed an MES model for aero-engine design industries for the improvement of assembly line efficiency and management. Several MES designs are also presented that use RFID approach to capture real time data. Jiwei Hua et al. [8] designed MES solution for textile industries with the help of RFID technology for real time data acquisition. Blanc Pascal and Castagna Pierre [18] proposed a holonic approach for MES design. The work of Luo Fei [9] describes a generalized MES structure which is capable of planning, scheduling, task management, production and collaboration with other system. FMCG industries run batch production that produces millions of production data in every second. These data are crucial to take decisions on manufacturing trends. Also if several production plants are spread over large geographical area, an efficient model is required to build easy communication between centralized ERP system and remote production servers. In our work we plan to propose an MES architecture for FMCG industries aiming an efficient communication model between ERP and MES.

## III. MES OVERVIEW

MES is a term defined by US Advanced Manufacturing Research (AMR). MES generally resides between ERP system and floor level control system. Some of the benefits of MES include:

- Reduction of waste and scraps,
- Faster setup times for equipments,
- Accuracy in cost-estimation (labour, scrap, downtime, uptime),
- Increased line uptime,
- Increased line efficiency,
- Quality Analysis, report generation,
- Maintenance.

As we aim for FMCG industries, the module structure of an FMCG industry generally includes Production, Quality and Maintenance. Fig. 2 shows a basic architecture of manufacturing levels [9].

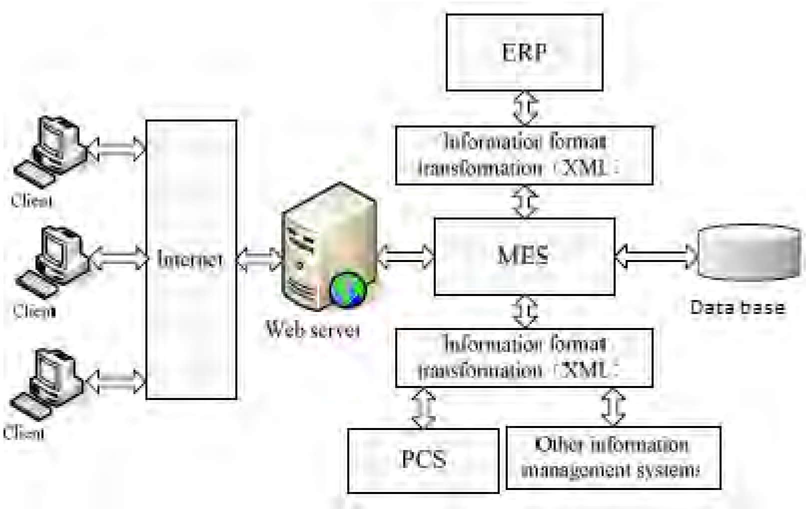


Fig 2: MES Architecture

MES technology is integrated with ISA-95 standard model with several relationships. MES is considered as level 3 system where control system hardwares, relays, drives and electro-mechanical machineries come in level 0, control system softwares like: SCADA and equipments such as: PLCs, data controllers machines (OPC etc.) come in level 1, historian server technology for data archiving can be considered in level 2 and ERP packages are considered as level 4 systems. In a manufacturing environment, other systems such as: LIMS (Laboratory Information Management System), Manufacturing Operations Management Systems (MOMS), Warehouse Management System (WMS), computerized maintenance management system (CMMS) etc. may also come along with MES. Label 0 systems generate, control and collect raw manufacturing data. Level 1 systems are meant for supervision and control of level 0 systems, capturing raw data at high rate, transforming raw data into machine understandable data format. Level 2 systems are used as a buffer between level 1 and level 3 systems which are meant for data collection at high rate and archiving those data before data reach to level 3 systems. MES comes in level 3 which can communicate with level 4 systems to capture production plans, to send analyzed production data and can also pass the control up to level 2.

## IV. EVENTS DEFINITION

Data acquisition in MES is based upon events that are generated during manufacturing process flow. An event can be defined as a change in any manufacturing process attribute due to some specific reason. It depicts an abstract description of production activities. Examples of some events are line downtime, production status change, line uptime, product change, crew schedule change, alarm generation etc. Each event may consist of several meta-events [13]. Meta-events are basic logical division of a single event. An event has several properties which are the characteristics of that event. MES aims to analyze those characteristics to decide the reason of an event. If event Ei occurs when unit is doing a certain operational activity OP1 and Ei starts some other operation OP2, certain rules Tri are to be incorporated. OP1 must have a preparation event which belongs to meta events set of Ei [10]. Fig. 3 shows the event creation process below.

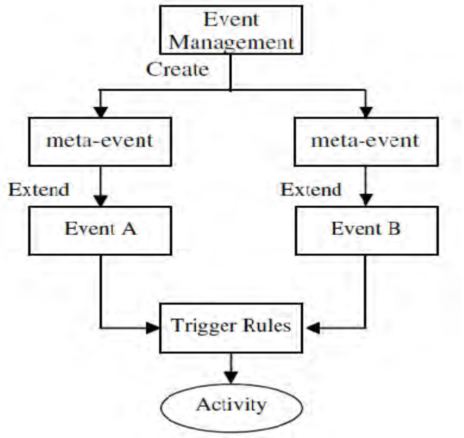


Fig 3: Events creation and triggering

## V. MES RECONFIGURABLE FRAMEWORK

Xisheng Lv et al. [10] proposed a basic MES reconfigurable framework that is followed in FMCG manufacturing industries in general as shown below (fig. 4)

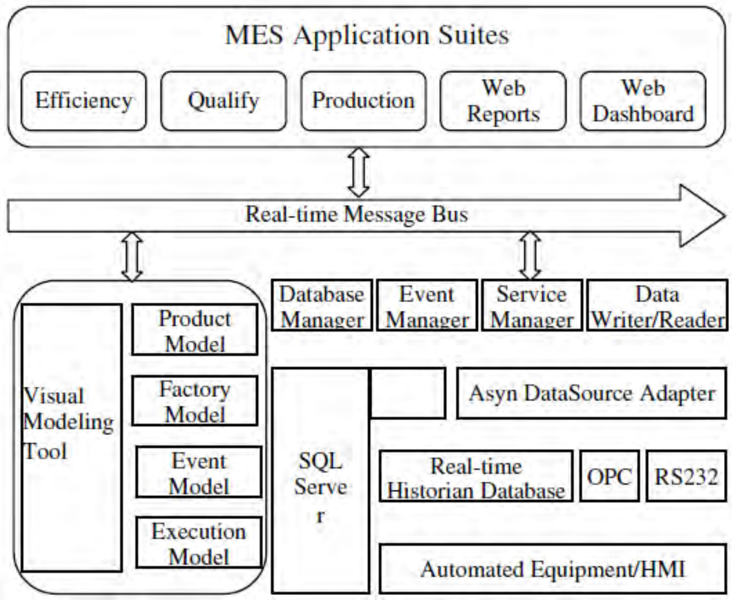


Fig 4: Structure of reconfigurable MES

MES aims to build a digital workshop by modelling product raw materials, product lines and material feeding. MES platform consists of real-time message exchange, infrastructure module, production module (factory, product, event and execution models), asynchronous data transfer and MES application suites which are defined in detail with a flow of basic semantic meta-objects. Warehouse resources, enterprise production resources and shop floor business are abstracted and classified. The Visual control and supervision tool are provided for describing real time flow at shop floor and controlling them remotely. Factory resources are defined as factory model, production activities are noted as event model and enterprise business as execution model. Any change in sequence of production activities is implemented by describing and controlling production event and product statuses, thus enables management to function as production planning, raw material input, production tracing and quality analysis. For tracking these changes as per production process, MES has been developed as an extremely customizable model based upon enterprises' process flow. A detailed study of MES system in mass customization environment has been presented by Huang Hailong et al [11].

## VI. PROPOSED SOLUTION

Manufacturing process can be classified into three groups such as: Continuous Manufacturing Process (like: Oil refinery), Discrete Manufacturing Process (like: Car manufacturing) and Batch Manufacturing Process (like: FMCG). As our solution aims for FMCG industries, we concentrate on batch manufacturing. The proposed solution tracks and analyzes production data based upon Batch Events. Existing solutions may not solve the integration and customizability of MES because they are not from the view of the whole job shop and production system [12] used in FMCG.

Our solution keeps the basic MES framework intact and improves the communication between ERP and MES by batch event detection approach. It also eases the passing of production plans and instructions from ERP level to basic control system. Basic architecture of the whole system is shown in fig. 5.

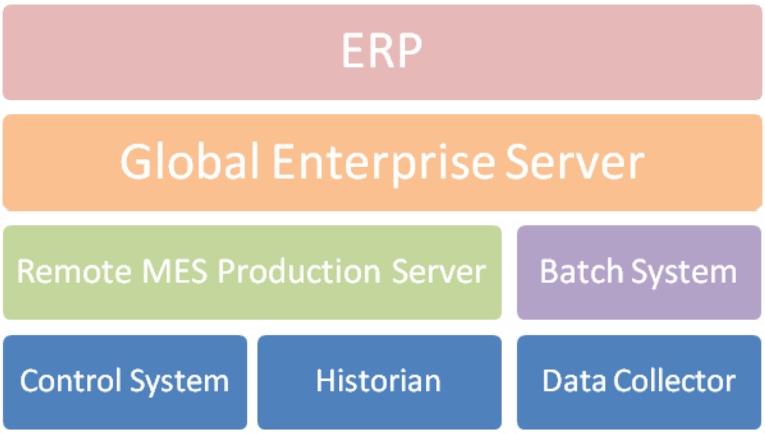


Fig 5: Block diagram of FMCG MES architecture

The business flow between ERP and MES has been classified as *downstream* and *upstream* communications. In downstream communication, production plan is scheduled in ERP as per market demand, managerial strategies and the complete production plan for individual batch process is converted into XML data. Data exchange in XML form is used to enable cross-platform, machine independent B2B (business to business) data exchange. XML files are further sent to Global Enterprise Server and stored. Whenever batch manufacturing is about to start at shop floor, the production plan data (XML data) are downloaded from global server to remote batch system. Batch system extracts the production plan data and schedules them in client view for further control. As the batch manufacturing process starts, production plans are activated manually or automatically and batch event is fired. The whole batch data gets uploaded into MES production server. Figure 6 shows the downstream communication process flow structure.

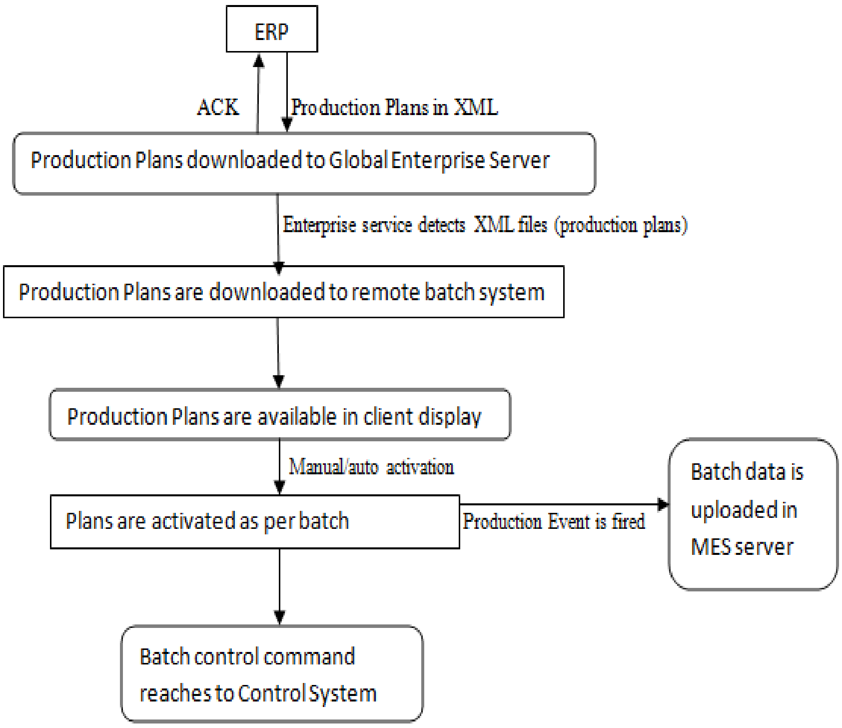


Fig 6: Downstream Communication Model

Once the batch is finished, control system generates a batch completion signal. This signal generates batch ending event in production (MES) server. Production server now starts capturing batch production data from control system. Based upon all captured data, MES server produces upstream communication messages to be sent to ERP syatem. Some general upstream messages are:

- **Planned production data:** Holds the detailed data of total planned products to be produced
- **Actual production data:** Holds the detailed data of batch products after production
- **Raw materials Consumption data:** Holds the detailed data of raw material consumption
- **Quality analysis data:** Holds the detailed data of quality testing

When these messages reaches to batch system, batch event detection system tracks the event and calculates production efficiency and loss based upon captured data. There can be two types of loss which can also be considered as *batch events* while calculating line efficiency–

- **Line loss event**: If production time exceeds the scheduled time due to unexpected downtime, critical maintenance work etc.
- **Line idle event**: If production is completed before scheduled time and line remains idle until raw materials for next production arrives.

Batch efficiency is calculated as per individual industry standards and the complete data is embedded into XML forms which are uploaded back into global enterprise server. Enterprise Server then sends back the files into ERP system. Figure 7 shows the upstream communication structure.

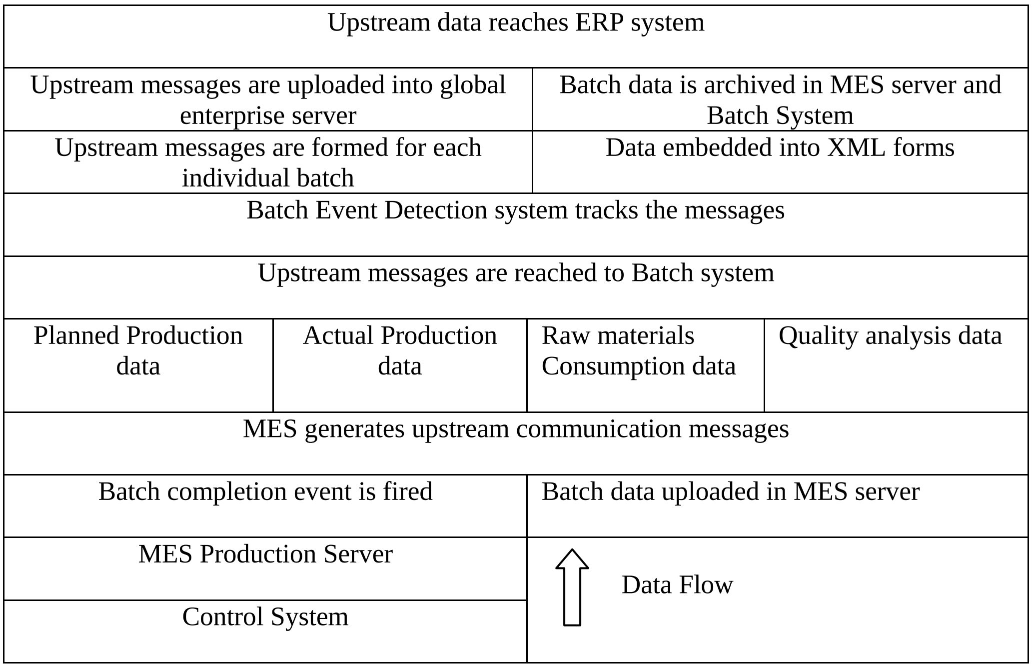


Fig 7: Batch data uploading structure

## VII. IMPLEMENTATION DETAILS

A prototype model of the proposed solution has been implemented successfully and tested as per industrial scenario. A model of Packaged Drinks production system has been considered as base model. A brief description of the Production model has been given below:

**Production Model**

- Business Unit: For a particular business type in an Enterprise.
- Production Lines: A complete production line. There can be multiple production lines in a single business unit.
- Production Units: Multiple production units in a single production line.
- Products: Multiple products to be run on a single line.
- Batch: A batch production process.
- User Accesses: Users accesses based upon roles.

A partial view of the production model plan is given below:

| Line | Units | production group | Variables | I/P Values | | O/P Values | | Specifications | | | Specifications | | | Alarms | | Events | Line Downtime Reasons | Measures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Digital | nalogu | Digital | Analogue | LL | Target | HL | LL | Target | HL | LL | HL | | | |
| | | | | | | | | Product001 | | | Product002 | | | | | | | |
| | | | Reactor_Drain | 0=ON, 1= close | | | | | | | | | | | | | | 1.Avearge Cpk |
| Line 001 | | | Reactor_Batch_Qty | | x | | | | | | | | | | | | | 2. check 10 samples every 30 min |
| | Bottle Hopper | | | | | | | | | | | | | | | 1. Production Event (Reactor_Drain =0) | | 3. Total PPM |
| | | | No_of_Bottles | | 0> | | | 995 | 10000 | 10005 | 995 | 10000 | 10005 | | | 3. Downtime event | DR2=Hopper Unit 1 Jam, DR2=Hopper Unit 2 Jam DR2=Hopper Unit 1 Failure, DR3=Hopper Unit 2 Failure, DR3=Bottle stuck DR3=Bottle breaked DR4=Motor stopped DR4=Oil pressure Low DR4= Oil Temp High | |
| | | | Unit_Status | 0=Running, 1 =fault | | | | | | | | | | | Fault | | | |

Fig 8: Partial Production Model Plan

The application consists of two background services to handle the communication and file transfer between ERP and MES systems. Two services namely *downstream* and *upstream services* have been developed as windows services having following features:

- The downstream service runs at Global Enterprise Server and upstream service runs at MES server.
- Downstream Service continuously checks for the availability of ERP data (XML data).
- Upstream Service continuously checks for the availability of batch data.
- If ERP data in the form of XML files are available, downstream service transfers the files to remote MES server using FTP (File Transfer Protocol). The service has been tested with transferring 20 XML files per second successfully.
- If batch data is available in batch system (SQL server), upstream service extracts the data from SQL server, transforms it into XML form and finally transfers the XML files to Enterprise server.
- If some files cannot be transferred, those are stored in a separate folder with log entries to help debugging the reason of failure.
- Both the services have file-archiving facility to be used as per enterprise requirements.

The central prototype model of MES has been developed as an application in C# with a central database to store Production Data. A partial view of the Entity Relationship diagram of MES Production server is given below:

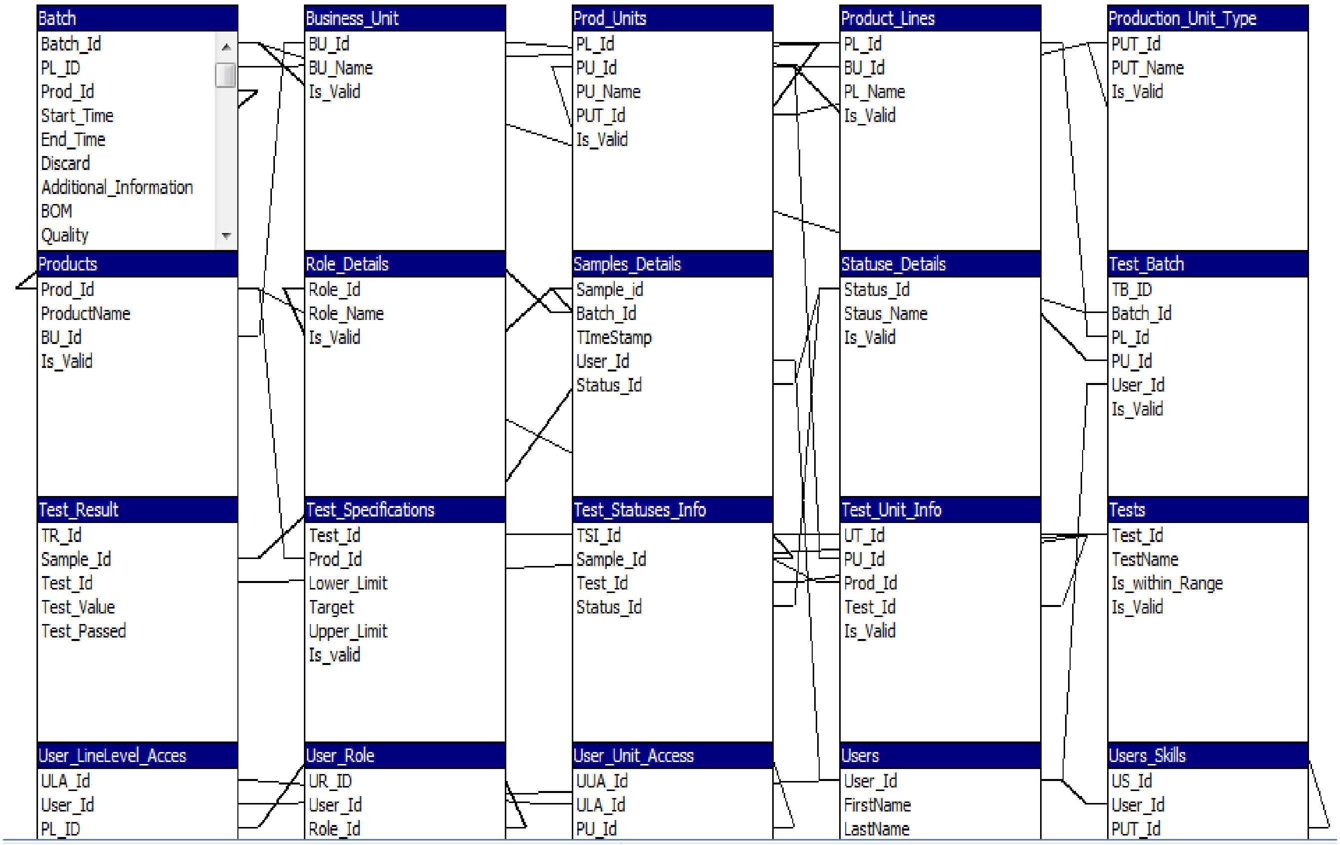


Fig 9: Partial representation of ER diagram of the Production Model

The ER diagram design has been carried out in MS Access for partial representation purpose. However SQL server has been used as backend MES production server.

## VIII. CONCLUSION

In this paper we have analyzed the production process in FMCG industries and presented an MES model customized for FMCG. However the same model can also be used in other industries after changing some basic configuration of production process. A prototype model has also been implemented and tested considering the real industrial scenario. We have successfully addressed MES performance attributes for establishing an effective 2-way communication between ERP and MES based upon batch event detection approach. Thus it reduces cost, man power with improved accuracy and reduced time. The next phase of this research work plans to address detailed production parameters and optimization of current model if needed, to develop the complete software architecture with customizable performance metrics, to develop the associated ubiquitous model for communicating with central system from remote locations with enhanced security and testing on larger industrial benchmarks with real time scenario as well. Detailed investigation and user-centric analysis of the complete design are also an area of further research interest.

## REFERENCES


[1] Peter F. Drucker, Ikujiro Nonaka, David A. Garvin, "Harvard business review on knowledge management", Harvard Business School Press, 1998.

[2] Sheng-Luen Chung, MuDer Jeng , “Manufacturing execution system (MES) for semiconductor manufacturing”, Systems, Man and Cybernetics, 2002 IEEE International Conference, Oct, 2002.

[3] Chen, R.S., Yung-Shun Tsai; Chan-Chine Chang, “Design and Implementation of an Intelligent Manufacturing Execution System for Semiconductor Manufacturing Industry”, Industrial Electronics, 2006 IEEE International Symposium, July, 2006.

[4] Ruey-Shun Chen, Yung-Shun Tsai, Chan-Chine Chang, “Design and Implementation of an Intelligent Manufacturing Execution System for Semiconductor Manufacturing Industry”, IEEE ISIE 2006, July 9-12, 2006.

[5] Wen-qian Cao, Shao-hong Jing, Xiao-hong Wang, “Research on Manufacturing Execution System for Cement Industry”, Industrial Electronics and Applications, 2008, IEEE Conference.

[6] Muhammad Younus,Lu Hu,Fan Yuqing,Cong Pei Yong, “Manufacturing Execution System for a Subsidiary of Aerospace Manufacturing Industry”, IEEE International Conference on Computer and Automation Engineering, 2009.

[7] Wang Shewei, Yang Haicheng, Mo Rong, “Research and Design of Assembly Manufacturing Execution System for Aero-engine”, 2011 Second International Conference on Digital Manufacturing & Automation, IEEE.

[8] Jiwei Hua, Tao Liang; Zhaoming Lei , Study and Design Real-Time Manufacturing Execution System Based on RFID, Intelligent Information Technology Application, 2008. IITA '08. Second International Symposium, IEEE.

[9] Luo Fei, “Manufacturing Execution System Design and Implementation”, 2010 2nd International Conference on Computer Engineering and Technology, IEEE, vol. 6.

[10] Xisheng Lv ,Haibo Shi,and Wenli Shang, “Reconfigurable Manufacturing Execution System Based on Events”, Wireless Communications, Networking and Mobile Computing, 2008. WiCOM '08. 4th International Conference.
[11] Huang Hailong, Liu Fei, Tang gan, “Manufacturing Execution System Based On Equipment Networked Operation For Mass Customization”, 2012 International Conference on Computer Science and Information Processing (CSIP).
[12] Li Bo, Chen Zheng hang, Chen Ying, “Research on reconfigurable manufacturing execution system,” Intelligent Mechatronics and Automation, 2004. Proceedings, 2004 International Conference on, pp.157-161, Aug. 26-31, 2004.
[13] Feng Quibin, Bratukhin Aleksey,and Treytl, Albert, “A Flexible Multi- Agent System Architecture for Plant Automation,” Industrial Informatics, 2007 5th IEEE International Conference ,vol.2,pp.1047- 1052, 23-27 June 2007.
[14] Fucheng Pan, Hui Peng, and Haibo Shi, “Event - Based Production Process Traceability Model,” in Intelligent Control and Automation, 2006. WCICA 2006. The Sixth World Congress on, vol. 2, pp.7211- 7215.June 2006.
[15] Wenli Shang,Hui, Peng,and Haibo, Shi, “Research of Primary Technique to Manufacturing Execution System Based on Digital Production Model,” Convergence Information Technology, 2007. International Conference on, pp. 2019 - 2023, 21-23 Nov. 2007.
[16] MESA. MES Explained: A High Level Vision. http://www.mesa.org/
[17] Jean Marcelo S, Paulo C, and Stadzisz G, “Manufacturing execution systems for customized production,” Journal of Materials Processing Technology, vol. 179, no.1-3, pp.268–275, October 2006.
[18] Pascal Blanc, Pierre Castagna, “A holonic approach for manufacturing execution system design: An industrial application,” Emerging Technologies & Factory Automation, 2007. ETFA. IEEE Conference on, pp.1239 – 1246, 25-28 Sept. 2007.