CHEMICAL ENGINEERING TRANSACTIONS

VOL. 66, 2018

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866150

Implementation of Chemical Process Virtualization Plant Based on Cloud Computing

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This paper expounds the implementation of virtual plant for chemical processes with cloud computing technology. With reference to domestic and foreign literature, we build a chemical process virtualization plant with cloud computing in light of relevant experience, followed by meta service resource layer, logical service resource layer, and application service resource layer as built therein. It turns out that the virtual plant implemented here can well control over chemical resources and improve the economic benefits of the company. In conclusion, not only can the implementation of chemical process virtualization plant based on cloud computing improve chemical production technology, but also the economic efficiency of businesses significantly beefs up, increasing the added value of chemical products.

1. Introduction

The construction of chemical process virtualization plant is cumbersome for it involves more expertise and technologies. In general, the heterogeneous environments required in the modeling process may differ a lot, such as data platforms, network protocols, and so on. Beyond that, network environment and information technology evolve at a faster pace, but the other way around, the demands of users will not be subjected to change with these factors. The above dilemma will pose a new challenge in the face of people when they construct a chemical process virtualization plant based on cloud computing. The constant development in IT industry has ushered people into a new era of cloud computing technology, this provides clues to the realization of chemical process virtualization plant. Cloud computing refers to the stored and retrieved resources in computing center that build on third-party businesses. It then better serves for users. At this stage, many scholars in China have carried out studies on cloud computing and applied it to various fields. With this technology, some scholars have built a smart grinding cloud platform; some also have established a set of coal production process supervision system

In this context, this paper, with reference to domestic and foreign literature and based on relevant experience, makes use of cloud computing technology to build a chemical process virtualization plant with meta service resource layer, logical service resource layer, and application service resource layer for the implementation. It is designed to further improve the economic benefits of chemical companies. In this sense, it has a great practical significance.

2. Literature review

Virtual manufacturing is defined as an integrated, comprehensive, and enabling manufacturing environment for improving decision-making and control at all levels. Its main functions are, through modelling and simulation, improving the quality of processing procedure, predicting product cost and controlling product cost and production. In addition, according to the computer simulated product development environment, the designer can simulate the manufacturing process before machining. The so-called product development here includes all activities related to the product, including not only technical and commercial, but also product design and production. Therefore, virtual manufacturing technology is a comprehensive technology formed by multidisciplinary knowledge. Its essence is to model the production process such as design and manufacture on the premise of computer-supported simulation technology. In the design stage of the product, the whole

Please cite this article as: Xu J., 2018, Implementation of chemical process virtualization plant based on cloud computing, Chemical Engineering Transactions, 66, 895-900 DOI:10.3303/CET1866150

process of product future manufacturing and its impact on product design are simulated in real time and in parallel, and the product quality, product manufacturing technology and product manufacturing are predicted, so as to organize the production more efficiently, economically, softly and flexibly. "Virtual manufacturing" has attracted wide attention of different fields. It has not only become one of the hot topics not only in the scientific and technological circles, but also in the business world. The reason is that, although the virtual manufacturing appears relatively short, its revolutionary impact on the manufacturing industry is rapidly showing, and many successful application examples emerge.

In foreign countries, the practical significance of virtual factories has been recognized by technicians, and the application of virtual reality technology to solve the problem of factory planning has a long history. Boeing Company has applied virtual reality technology in 1970s, and by 1990s, it has realized the production of 777 airliners without drawing, and then it began to apply virtual reality technology to the design of fighter. The successful experience of Boeing has inspired the technicians all over the world, and the larger production industries, such as automobiles and crude oil, have invested in the application research of virtual reality technology. Wilson and others abroad applied virtual reality technology in the Rover Gorup Powertrian project for layout design in 1996. It was used to communicate and find potential problems and project evaluation for technicians. They realized equipment layout, physical system, buffer station and storage system in virtual environment. This research showed that virtual reality technology was a powerful auxiliary tool for engineers. With the increase of application, some CAD systems added the plug-ins or modules planned by the factory. For example, the Plant Layout of CAITA also applied the 3DMax such kind of software for 3D layout planning, but these systems lack the real-time performance of the virtual reality system. Some special layout or logistics planning software also came into being, such as QUEST, ModelFlow and so on. In addition, some research projects compare the results of immersion and desktop systems. Shamsuzzoha and others compared HMD systems and desktop systems in the development of virtual layout systems. And they concluded that the immersion system using HDM was more satisfying and should be fully applied (Shamsuzzoha et al., 2016). At this stage, the direction of foreign research integrates into the virtual system and physical system. It is a hot topic to guide and train workers through augmented reality virtual reality technology. BMW Company designs a virtual system to assist the assembly of automobile doors and windows. The sound they use compensates for the lack of force feedback system.

Kunz and other scholars designed a virtual system control workshop production scheduling, which allowed multiple users to interact, remote control CNC machine tools, and the system for personnel training. In addition, they developed a network-based, distributed system that assisted technicians at different locations to work together or to conduct remote monitoring and command (Kunz et al., 2016). Ulewicz and others developed the 300mm chip manufacturing workshop simulation system with VRML technology, including more than 20 chip production devices, which allowed engineers to modify the design and simulate through the network (Ulewicz et al., 2016). Xu and so on designed the ModFact virtual factory system and LON (Local Operating Network) to control the physical production system (Xu et al., 2016). Petersen and others implemented the communication of virtual devices and real devices using the MMS (Manufacturing Message Specification) standard (Petersen et al., 2016). Hao and so on designed the Http-connected test system to interact with the machine through the network (Hao et al., 2016).

In China, since 1990s, the CIMS center of Tsinghua University and some other research centers of universities have also devoted themselves to the research of virtual production line. Shahid and Sharif used the methods of WTK and Agent to design the virtual production line system (Shahid and Sharif, 2015). Anon also used virtual reality technology to evaluate and transform the existing crankshaft production line, and improved the utilization ratio of equipment (Anon, 2016). Sun Liansheng and others at Beijing Institute of Technology developed a visual design system for production line, which was designed through 2D and 3D mapping. The IMMS developed by Tsinghua University can be used in the design of the manufacturing workshop; the Nankai University developed the JobShop scheduling simulation software for the workshop scheduling simulation, and based on the FASE developed by the Tsinghua University and the 204 units of the Ministry of space, the intelligent rule scheduling system was developed. But these systems have not been widely applied for various reasons, and have even stopped the subsequent development.

To sum up, the domestic application of virtual reality for factory layout planning is still in the stage of experimental research, and the practical application of foreign industrial giants (such as Boeing and BMW mentioned in the previous part) is lacking. It should be seen that the research history of the foreign counterparts is long and the investment is larger than that of the domestic. The result is the accumulation of investment for many years. It is difficult to catch up with the foreign level in the short term. This paper has made some exploration in the field of virtual factory layout planning, expecting to play a positive reference role.

3. Method

Like the cloud manufacturing technology system, the virtual plant technology system based on cloud computing is a hierarchical architecture, including the resource layer, middleware layer, core service layer, and application layer, as shown in Figure1. Among them, the resource layer covers design, simulation, production, experiment, integrated and management resources, etc., and the upward is embodied in two forms: virtualized manufacture resources and service capacity resources. The middleware layer supports the virtualization, service, access, perception, and collaboration middleware of various resources; the core service layer, based on the interface of the middleware layer, provides various functions that are essential to the cloud computing simulation service platform, including service deployment/registration, service search/match, service combination/scheduling, service operation/fault tolerance, service monitoring/assessment, and service pricing/billing; the portal layer is a universal, efficient cloud manufacture support platform, generally as service providers, platform operator and service users.

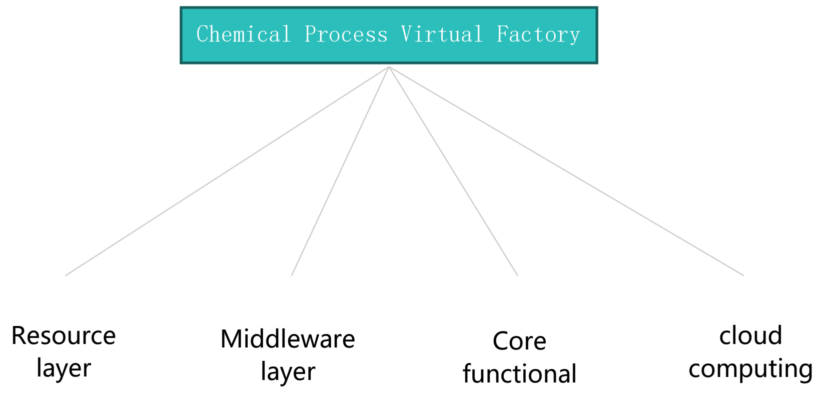

Figure 1: Virtual factory based on cloud computing

Cloud computing virtualize and make all resources serviceable, aggregates these virtual resources in a virtual resource pool, and allocates and integrates resources as required in business applications in order to achieve flat management of resources. The combinatorial computing features as follows: (l) elasticity. Cloud computing can increase or decrease the appropriate IT resources according to the number of access users, so that the IT resources can be dynamically scaled in and out to respond to change in the scales of applications and users. (2) rapid deployment. The cloud computing mode is extremely flexible, enough to adapt to various types and scales of applications in the development and deployment phases. Providers can deploy resources in a timely manner depending upon the needs of users, and end users can also select these on demand. (3) resource abstraction: it is not required for end user to know where there are specific physical resources applied on the cloud, while the cloud computing supports the user to use the application services at various terminals wherever they are available. The requested resources come from the “cloud” instead of the fixed tangible entity applied to the “cloud”. In fact, the user does not need to understand and consider where the applications really operate. Cloud computing model is shown in Figure 2.

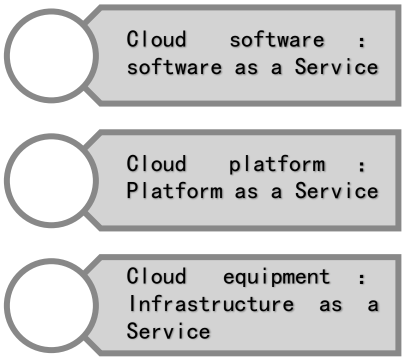

Figure 2: Cloud computing types

4. Results and discussion

4.1 Virtual plant cloud computing platform architecture model

In the chemical process virtualization plant, the 3D cloud built based on virtual reality technology provides users with plant roaming and freedom browsing in 3D scenarios, as well as interactive operation environment so that the users feel like they're really there. Among them, in the interactive operation environment, the data integration faces a complex and volatile challenge with different operating objects and services, while cloud computing can provide extremely flexible resources. Its unique technology has unlimited scalability that exactly fits for the complex business portfolio of virtual plants. Cloud computing can quickly aggregate resources as required and gradually grow up by dispatching multiple servers to a task, and can scale in, hibernate, or disappear when it is not required. Therefore, cloud computing can not only adapt to sporadic and periodic or temporary works, but also integrate flexible, self-managed, and highly scalable application system through service portfolio.
In face of immense hardware and software resources, according to complex and volatile demands for business expansions in chemical process virtualization plant, cloud computing platform requires an architecture different from the previous system integration. In general, system integration adopts hierarchical management model so that it depends on growing hierarchies to gradually refine business applications. However, this model will make the system more and more complex and further make it difficult to scale out. To make sure that the virtual plant cloud computing platform has a strong scalability, the cloud computing platform architecture may be designed as a flat three-layer structure, as shown in Figure 3.

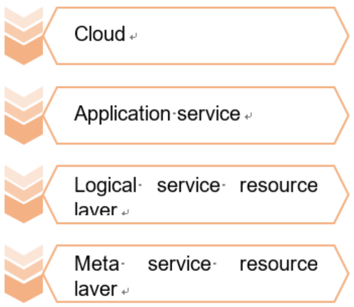

Figure 3: Model of cloud computing Platform

Meta service resource layer. At this layer, all hardware, network and storage devices, operating systems, databases, and application software are abstractly transformed into service resources from the IaaS to the SaaS layers through virtualization and serviceability. The originally numerous types of complex resources are combined into one in order to simplify the objects of system integration and reduce the complexity of service portfolio.
Logical service resource layer. At this layer, for the characteristics of the chemical process industry, the fine-grained raw service resources at the meta service resource layer are combined into a coarse-grained business logic service to allow it to have certain self-management, self-repairing, and self-deploying capacity, so that an efficient reusable service resource can be provided for the application service layer, as shown in Figure 4.

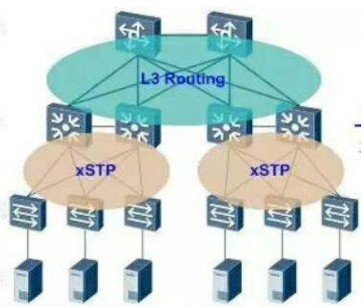

Figure 4: Logical server virtualization technology

Application service layer. In the application service layer, according to specific business applications, SOA's service composition strategy is used to quickly build an interoperable and evolutional type of distributed software applications with home-made, platform-standalone, loosely coupling and reusable services at the logic service resource layer as underlying units, which enables them to respond quickly and flexibly to the frequent changes in chemical process virtual plant operations.

4.2 Application case for cloud computing platform

In the ethylene industry production, the cracking furnace as one of the core devices plays a decisive role. When simulating ethylene equipment, in order to improve the production efficiency and the design of the cracking furnace, the fluid dynamics calculation software Fluent is required to calculate the physical quantities such as the flow rate, temperature and composition of the flue gas in the cracking furnace. When computing these using Fluent, iterations are often required. since a computer will be unable to perform this type of calculation in a relatively short period of time. In order to maximize the calculation efficiency, a parallel calculation is generally used. As computing resources are not infinite, not only will the computation time be reduced, but the utilization rate of computing resources should also be improved. It is feasible to build a flexibly extending and scaleable Fluent parallel environment by using cloud computing.
Cloud computing-based virtual plant use some technologies such as virtual reality technology, cloud computing technology, and Webservices to achieve green, serviceable, and intelligent models, control, and optimization and integration based on the characteristics of the chemical process industry. The overall architecture of the virtual plant is shown in Figure 5 and 6.

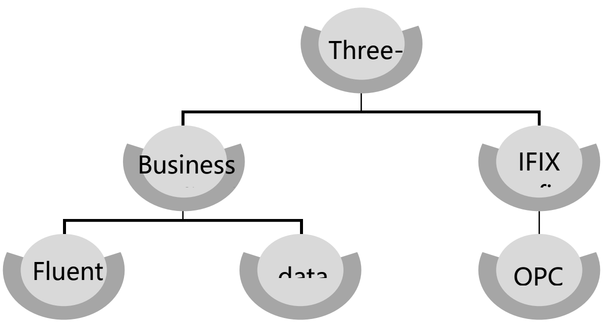

Figure 5: Chemical Process Virtual Factory Architecture

Figure 6: Cloud Computing Virtualization Data Centre

There are two parts: one is a 3D cloud based on 3D virtual reality technology; the other is a chemical cloud computing platform which adopts the open-source cloud computing system OPenstack to build a dynamically expanded cloud computing environment with the KVM virtual machine technology in order to capture virtualized and serviceable hardware and software.
In the cloud computing platform, a dynamic model carrier for ethylene glycol, ethylene, polycool, and PTA is implemented in the form of a virtual machine. In the scale of the dynamic model, the dynamic model can be divided into multiple sub-models that will be deployed on multiple virtual machines. A virtual VLAN network in the cloud platform achieves mutual communication and data interaction.
After the ethylene 3D cloud terminal sends a service request for the cracking furnace simulation and optimization data to the cloud computing platform via the Web Service, since the corresponding application service in the cloud platform is composed of several subservices including the Fluid Mechanics Fluent Computation Service for the cracking furnace, the application service layer breaks up this task into several subtasks and submit them to their respective subservices for execution. After the Fluent computation service

received the calculation request, initial 4 Fluent computation nodes are virtualized in the cloud computing platform with the KVM virtual machine, where it starts computing. While the cloud platform performance load supervision service supervises and evaluates the tasks that currently operate on 4 computation nodes. When too heavy load is found, a computing resource expansion request is issued to the Fluent computation service which virtual adds more nodes based on resource utilization of the computing cluster to the current cracking furnace hydrodynamic calculations, in order to achieve the elastic expansion of computing services. When the calculation task is completed, the calculation result is submitted to the ethylene dynamic model via the Web Service after the aggregation process, where its availability is verified. The optimized results can be timely viewed based on Web Service data communication between the 3D cloud and the dynamic model of ethylene, while clearing the Fluent computation nodes where no task is assigned from the cloud platform to release the resources.

5. Conclusion

Here is the virtual plant model for chemical process. An example is cited here to reveal the application effect of the model. Study results show that, if the chemical process virtualization plant integrates cloud computing technology, it can achieve good control over chemical resources by means of meta-service resource layer, logical resource layer, and application service layer, thereby to improve the economic benefits of businesses. It follows that the implementation of a chemical process virtualization plant based on cloud computing can not only improve the chemical production technology, but also significantly boost the economic benefits of the businesses, while increasing the added value of chemical products.

At this stage, many scholars in China have carried out the studies on cloud computing and applied it to various fields. Some have built a smart grinding cloud platform with this technology. Some have built a set of coal production process supervision system based on this technology. Therefore, cloud computing technology has a great potential for future development. As cloud computing and chemical process virtual plant involve many disciplines, it is inevitable that this study may have some gaps needed to be further explored.

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