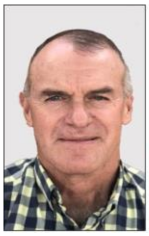
Third Generation Modularisation

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Introduction

The development of modularisation in the process industry, from Generation 1 (G1) to Generation 3 (G3), was discussed in an earlier Insight Article (Steyn & van Heerden, 2015). The authors described the drivers, benefits, disadvantages, and risks of process modularisation. The advantages of a modularised approach generally lead to an improved return on investment and project nett present value (NPV) because of a lower total installed cost and shorter construction schedule.

G1 modules have been constructed since the early '90s and were limited to main pipe racks with the main piping pre-installed. G2 modules were built from early 2000. This involved the installation of piping and main equipment in the modules, primarily all steel equipment. This approach reduced the field work by approximately 30 to 40%. G3 modules take the concept further to describe modularised process units. These process units contain 95% of steel work, up to 85% of the electrical installation and up to 95% of the instrumentation. This enables loop checking to be done in the module yard. G3 modules effectively relocate 90% of the field work to the module yard.

In this article, we build on that 2015 article and discuss G3 modules in more detail. We focus on the more salient and practical issues during the development of a modular approach and explore the benefits of G3 modules. We also look at the appropriate approach, the risks and when not to do modularisation. Finally, case studies are presented of the outcome of modularisation work in which the authors were personally involved.

History of G3 modules

Fluor played a leading role in developing G3 modularisation (Haney, 2012; Chandler, 2013; Fluor Corporation, 2015). In early 2009, the Fluor team examined barriers to increasing modularisation beyond G2 to create a real step change, like the change from G1 to G2 modules. Their work process included the following steps:

- Brainstorming to identify opportunities;
- Reviewing methods and techniques used in offshore modules;

- Considering the number of interconnects between modules with the intent to develop modules that incorporate full unit operations with a minimum number of interconnections between modules;
- Distribution of electrical and instrumentation hubs throughout the facility to give each module distributed instrumentation, control and electrical functionality; and
- Reviewing other enabling technologies (e.g. cable connectors such that instrumentation and electrical connections can be done simply and easily).

Fluor’s Fred Haney and his team subsequently patented the concept of the modular processing facility, their G3 approach, in 2012 (Haney et al, 2012). An example of a G3 module is shown in Figure 1.

Figure 1: Third generation module for an LNG plant

Key requisites for modularisation to work

A modularisation philosophy needs to be developed very early on for the project. At the end of the feasibility study (FEL2), the overall concept must already be well entrenched. Meyer et al (2012) highlight the need for early modularisation definition and logistics requirements. In developing the philosophy, the logistic constraints and site-specific conditions must be clearly understood and considered. Many modules will arrive at some nearby harbour. The size of modules and the weight that can be accommodated both in the harbour and en-route to the site will have a major impact on the overall philosophy.

If the site is not close to a port with good access to the site, it may be required to deliver the modules in subsections and have a staging and final assembly yard close to the final placement site. The necessary infrastructure can be made available to assemble and test a module at the assembly yard before it is moved to its final position on site. Staging facilities at site are anyway necessary, as modules will not arrive in a 'just-in-time' fashion, such that they can be moved into their final position upon arrival.

Fabrication facilities must be available with module manufacturing capabilities, whether in country, or overseas. The project team must do their own research on the location and capability of module yards globally to ensure that up to date information is available. The move toward modularisation is accelerating rapidly and up to date information is essential.

Figure 2 shows a module offloading berth with a crane unloading a module onto the berth and the module being moved along the road.

Figure 2: Modules being offloaded and transportation of module to site

G3 modular execution

Benefits

The advantages gained from a G3 approach generally lead to an improved return on investment and project NPV because of a lower total installed cost and shorter construction schedule. The key benefits are cost reduction, cost and schedule certainty and improved safety and quality, as described in more detail below:

- **Installed cost reduction:** Moving activities off site to a module yard results in improved productivity and lower labour rates. Because modules can be fabricated in various module yards, labour is more distributed, making it easier to source scarce resources and reduce the peak manpower load at the site significantly. A result often not properly understood or evaluated is the reduction in overall plant footprint, especially for G3 modules. Bulk materials like piping, cabling and structural steel for pipe racks are significantly reduced because of the reduced footprint.

- **Cost and schedule certainty:** Because modules are being constructed in controlled environments with the necessary facilities, cost and schedule are found to be much more certain as compared to a stick-built facility.
- **Improved safety and quality:** Module yards are set up to handle large modules and provide safer conditions with the right infrastructure during fabrication. For example, access for working at heights can be much more safely provided when compared to the normal practice of extended scaffolding on site. As module yards are set-up with a long-term mindset, issues like quality control, both of incoming materials and fabrication, is generally more effective.

Layout/Plot plan

A key difference in the G3 work process is that modularisation drives plant layout, rather than the G2 approach where the plant layout was typically like a stick-built plant. For G2, the modules were then determined by 'cutting' the layout into sections called modules. This approach led to numerous interconnections for piping, cabling, etc. In comparison, a G3 approach requires:

- **Minimal input and output connections:** Combine all the equipment for a specific unit operation into a single module (e.g. a crude distillation unit). The objective is that the module receives one feed and deliver one, two or three final products. All operations to achieve this is contained within the module. Utilities need to be supplied to the module, as required;
- **Team approach to plot plan development:** It is essential that the plot plan development is a team effort. All disciplines need to collaborate as an integrated team. This development is typically an iterative process. If the integrated approach is not successful, it will result in huge interdisciplinary impacts (and cost/schedule delays). The 'best' layout is one with maximum modularisation and a 4- to 6-week period should be allowed to finalise the layout; and
- **Early design freeze:** At this stage, it must be clear to the reader that, in order to be successful, earlier than normal 'freezing' of key equipment/concepts and a rigorous change management process is essential. It is also necessary that individual process block model reviews are completed before the overall plot plan review.

Design engineering requirements

In order to achieve the key objectives for a G3 module the engineering team needs to approach the design in a very different manner. This is not always easy, as one tends to revert to the familiar. The project leader(s) will need to keep challenging the team and make sure that the change management process is used (especially for a team where these concepts are new). The following list highlights key differences (Haney, 2012):

- Interconnecting pipe racks are not used;
- Offshore design practices are utilised, where practical;
- Schedule interdependencies are critical to success;
- Vendor data (particularly with packaged units) to support the design critical path is required early on. Thus, the selection and involvement of key vendors early in the design;
- The need for future expandability needs to be agreed upfront (you cannot add on in the future);
- Weight management of modules is critical to success and using an effective “load shedding” plan is required;
- Process design cannot change after completion of Front-End Engineering Design (FEED). Success depends on finalising process design at the end of FEED;
- Finalising of process datasheets is critical to support early vendor selection and involvement;
- Process control finalisation is required much earlier than normal. This is especially critical on packaged equipment; and
- Early constructability input into the development of the plot plan is critical because it helps ensure future access for operations and maintenance requirements; addresses module/equipment rigging and field erection issues; and facilitates development of equipment arrangement to ensure arrangement supports vendor/supplier layout requirements.

The owner’s personnel need to buy into G3 modular concepts and owner’s operations personnel are required to participate during FEED to validate the design layout. This is a particularly important point as the owner personnel need to accept the facility from the constructor and be able to operate it for the next 20 to 30 years. Owner personnel not familiar with the design, layout and operations and maintenance techniques used on this type of facility will not accept the design as workable. It may be necessary to have key personnel seconded to such a facility for an extended period (3 months, at least). They need to work in similar jobs to see, feel, taste, and learn before they become part of the owner team ‘back home’.

Material handling studies are very important during design validation and each activity (e.g. catalyst change, heat exchanger tube bundle removal) needs to be worked through step by step to ensure the activity can be performed. Because of the compactness of the modules, normal maintenance procedures like using a crane to remove a pump can generally not be done. Special davids, crawl beams, local hoists, etc., are often required to enable effective operation. If, during start-up or later in operation, it is discovered that special tools are required, if is very difficult, if not impossible, to install.

Practical Examples

The benefits of footprint reduction are often not properly understood when considering modularisation. In a complex plant (e.g. refinery) consisting of various processing units, plot space required can be subdivided into two aspects, namely the area required for a single unit (example 1) and the area required for the complete facility (example 2).

Example 1 – Process units

As G3 modules integrate complete processing units into single large modules, there is a great opportunity to reduce the area required for a processing unit. In the example shown in Figure 3 (based on an actual project), it was found that the footprint of the unit could be reduced by 35%. This was somewhat less than what was expected as the area required for the air coolers was limiting.

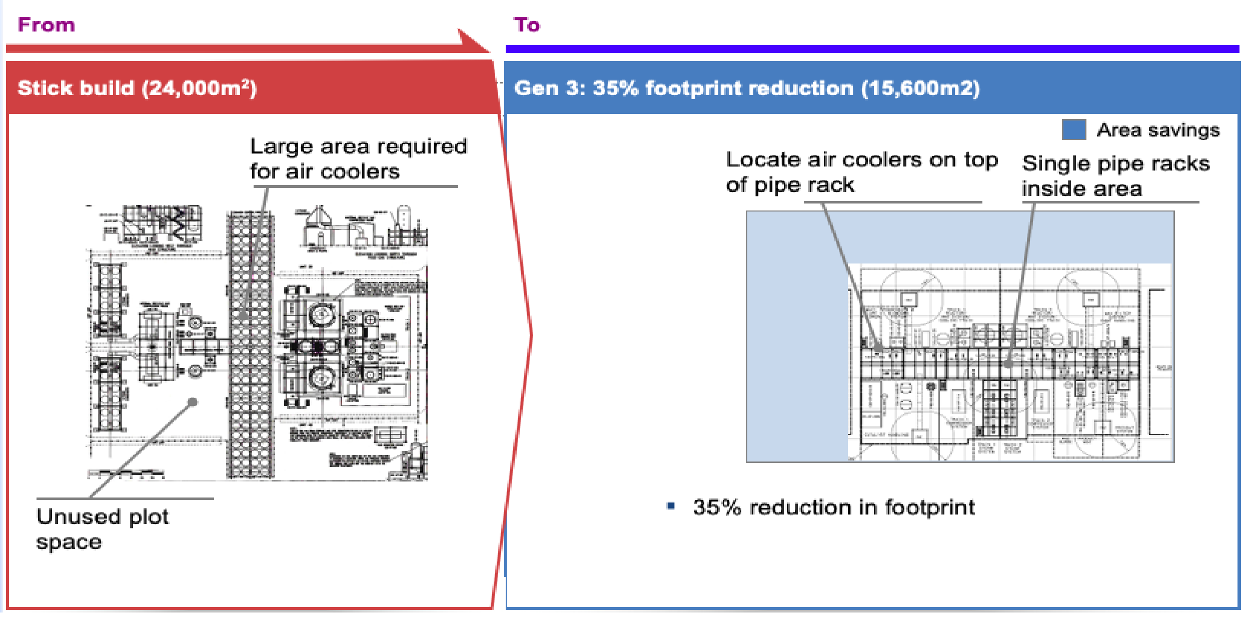

Figure 3: Plot space required for processing unit

Considering the location of the site and access, it was required to split the integrated module into 7 sub-units and 26 sub-assemblies, or modules. These modules were assembled in various module assembly yards. The maximum size and weight of the modules are given in Table 1.

Table 1: Detail for modules

	Conventional G2	G3 Modularisation
Layout	• 24 000m²	• 15 000m2 (35% reduction in area) – Area requirements driven by air coolers. – Can reduce footprint further by changing to water coolers.
Concept	• 7 Sub-units only • Break up into modules after finalising layout	• 7 sub-units, 26 modules • Maximum size per module 10m x 10m x 25m • Maximum weight per module 600 tonnes • Scheuerle trailer configuration • 1 to 6 modules per ship
Savings	• Between 7 and 8,5% savings in total cost	• 12,5 to 15% savings in total cost • 4 to 5 months schedule compression

A detailed bottoms-up estimate showed that the end-of-job cost could be reduced by 12 to 15.5% as compared to a stick-built plant and by 7 to 8.5% as compared to G2 modularisation. Very significant is also schedule reduction of 4 to 5 months in an overall schedule of 48 months. This could be achieved by distributing the work amongst various experienced module yards.

Example 2 – Complete facility

The facility consisted of several large processing units, steam and power generation, as well as other utilities and infrastructure.

The overall plot space could be reduced by 40% and on-site labour reduced by 50 to 60%. The overall NPV of the project (as compared to stick-built) increased by between 300 and 370 million US$ and the IRR between 0,9 to 1,3%, as illustrated in Figure 4.

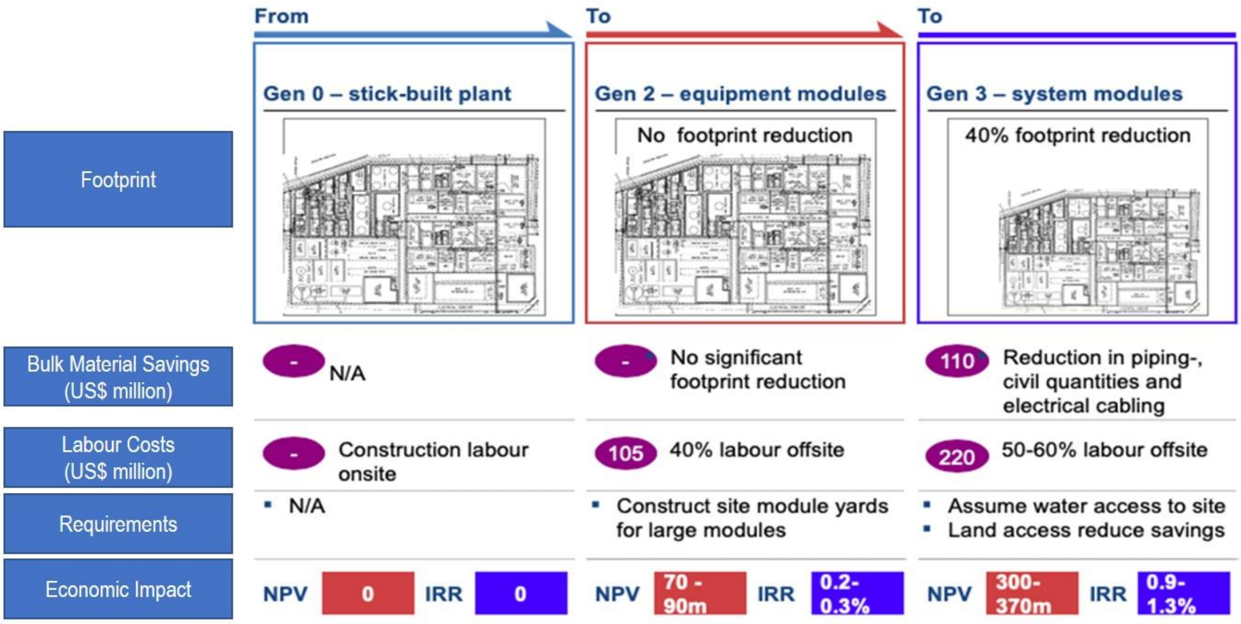

Figure 4: Overview of saving achieved for total facility

Know when not to modularise

After all the discussion and preaching the benefits of modularisation, one needs to be aware that modularisation is not the golden bullet that solves all project cost and schedule issues. There are instances when this approach should not be used, as described below:

- **Unproven process technologies:** The process needs to be proven commercially, otherwise design cannot be frozen early in the FEED process. An untested or new process step has the risk that process modifications may be required during commissioning or operation. The normal practice of having a 'start-up modifications' budget allowance is not practical. If a jump-over is needed for start-up, it needs to be designed in from the start.

- **Location limitations:** If the location limits site access severely and only very small modules can be moved, it may be more effective to revert to G2 modules. Inland locations can easily halve the savings.
- **Inexperienced engineering contractor:** It is essential to use an engineering contractor with modularisation experience. If this is not possible do not consider modularisation. The risk is too high and there are many horror stories and business school case studies of how not to execute a modular project.
- **Impossible to mobilise resources early in project:** Successful modularisation requires more upfront detail engineering and capital expenditure. If the stakeholders cannot be convinced of the need for earlier cash flow and resource mobilisation, modularisation may not be possible. 25% of detail engineering needs to be complete by the final investment decision, vs. perhaps 2 to 3 % for a stick-built plant.
- **Impossible to pre-select key contractors:** If the company's commercial practices require strict competitive bidding for EPC contractors, or for key equipment and packages, modularisation may not be the preferred approach. Modularisation requires early selection of key contractors and vendors that need to work in a partnership mode throughout the project. Continuity of key personnel is essential.

Concluding remarks

We hope that this article has at least sparked an interest in considering G3 modularisation on your next project. It is certainly worthwhile to consider and, if executed properly, can improve the project outcome significantly.

We have also pointed out that modularisation should not be tackled half-heartedly and that it is not for the faint-hearted. An absolute conviction as to the benefits, rigour, attention to detail and effective change management is required to make a G3 modularised project a success.

As shown, there are occasions when modularisation is not advised. Do not try to commercially prove an untested technology using a G3 modular approach.

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