Design of Manufacturing Cell for a Medium Voltage Vacuum Circuit Breaker

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Abstract - *In Today's competitive environment organizations require efficient operations to sustain. Layout planning has clear impact with the quality and quantity of the final products by reducing waste and improving efficiency. A Manufacturing cell is essentially a production line (or layout by product) for a group or family of similar items. It is an alternative to layout and organization by process or operations. The principal physical change made with a manufacturing cell is to reduce the distance between operations. In turn, this reduces material handling, cycle times, inventory, quality problems and space requirements. Organizations use technology to gain an advantage over the competition; however technology comes at its own cost. The price paid for the technology brings new challenges of accommodating the new technology into the existing setup. Due to the huge amount of investment required to develop appropriate setup to accommodate new technologies, a structured approach is required to plan them; so that they can be efficient in today's scenario and also cater the increased future demand with no or less investment later. This report describes the implementation of Systematic Layout Planning Methodology for planning a Manufacturing cell (production line) for Assembling a Medium Voltage Vacuum Circuit Breaker.*

Key Words: **Manufacturing Cell, Takt time, Cycle time, SLP, VCB.**

1. INTRODUCTION

In Today's competitive environment organizations require efficient operations to sustain. Along with efficient operations Organizations use technology to gain an advantage over the competition; however technology comes at its own cost. The price paid for the technology brings new challenges of accommodating the new technology into the existing setup. Due to the huge amount of investment required to develop appropriate setup to accommodate new technologies, a structured approach is required to plan them; so that they can be efficient in today's scenario and also cater the increased future demand with no or less investment later.

A major switchgear manufacturer in Mumbai, India faced a similar challenge of integrating their newly developed series of vacuum circuit breakers (VCB) into their operations. Due to the differences in the manufacturing of newer series of Medium Voltage Vacuum Circuit Breakers (MV VCB) and the traditional MV VCBs manufactured, hence it was agreed to dedicate an independent area for production of newer series of MV VCBs. Though the initial demand of a new product is low at the time of its launch in the market, the demand may shoot up any moment and the existing operations must be flexible enough to withstand the fluctuations in the demand without any need for modifications to the existing setup or provide enough time to plan for an add-on production setup. As modifications required would not only cost huge sum of monetary inputs but the delay in production caused due to increased demand may lead to a loss of business.

Layout planning has clear impact with the quality and quantity of the final products by reducing waste and improving efficiency. There is significant direct benefit for designing layout to improve the overall quality of production. The main advantages are to minimize workforce, inventory, and space to ensure quality of products exceeds customer needs. There is a positive relationship between the effective layout planning and total cost of waste minimization. Additionally, utilizing existing resources to produce more is the key to success for any manufacturing operation [1].

Systematic Layout Planning (SLP), developed by Richard Muther in 1978, is widely used in the manufacturing industry for facility layout planning. SLP includes three specific phases, Data collection and analysis; searching among the possible layout solutions & evaluating alternatives and the choice of the best layout [2]. The present work aims at using the Systematic Layout Planning approach for planning the **Error! Reference source not found.** at the production facility of the major switchgear manufacturer to manufacture the newer series of VCBs.

2. LITERATURE REVIEW

2.1 Manufacturing Cells

The basic elements in any layout planning are PQRST – Product, Quantity, Routing, Supporting Services and Time [3]. Layout should be planned to minimize material handling, maintain high turnover of work-in-process, hold down investment in equipment, make economical use of production area, promote effective utilization of manpower, and provide for employee convenience, safety and comfort in doing work [4]. A flexible layout is one that maintains low material handling costs despite fluctuations in the product demand levels [5]. The layout-by-product (Manufacturing Cell) was considered to be implemented for manufacturing of newer series of VCBs. A cell is essentially a production line (or layout by product) for a group or family of similar items. It is an alternative to layout and organization by process, in which materials typically move through successive departments of similar processes or operations. This layout by process generally leads to higher inventories as parts wait between departmental operations, especially if larger batches or lots are produced. There is more material handling required to move between departments, and overall processing time is longer. Exposure to quality problems is greater, since more time may pass and more non-conforming parts may be produced before the downstream department notices a problem [6]. Three aspects—physical, procedural and personal—must be addressed when planning a manufacturing cell. Cells consist of physical facilities such layout, material handling, machinery and utilities. Cells also require operating procedures for quality, engineering, materials management, maintenance and accounting. And because cells employ personnel in various jobs and capacities, they also require police, organizational structure, leadership, and training [6].

2.2 Types of Manufacturing Cells

Cells take different forms based upon the characteristics of the parts and Quantities produced, the nature of the process sequence or routing employed.

Cells are typically used to serve the broad middle range of a Product-Quantity (P-Q) distribution. Very high quantities of a part or product – typically above 1 million units per year – lend themselves to dedicated mass-production techniques such as high-speed automation, progressive assembly lines, or transfer machines. At the other extreme, very low quantities and intermittent production are insufficient to justify the dedicated resources of a cell. Items at this end of the P-Q curve are best produced in a general-purpose job shop. In between these quantity extremes, are the many items, parts or products that may be grouped or combined in some way to justify the formation of one or more manufacturing cells.

Within the middle range, a production line cell may be dedicated to one or few high-volume items. This type of cell will have many of the attributes of a traditional progressive line, but is usually less mechanized or automated.

Medium and lower production quantities are typically manufactured in group technology or group-of-parts cells. These are the most common types of cells. They exhibit progressive flow, but the variety of parts and routings works against a production line.

If the processing steps are specialized in some way, requiring special machinery and utilities, or special enclosures of some kind, then a functional cell may be appropriate. Functional cells are often used for painting, plating, heat treating, specialized cleaning, and similar batch or environmentally sensitive operations. If the functional cell processes parts for other group-of-parts or production line cells it will introduce extra handling, cycle time and inventory since parts must be transported and held ahead of and behind the functional cell. For this reason, planners should first examine the practicality of decentralizing or duplicating the specialized process(es) into group-of-parts or production line cells [6].

2.3 Layout and Flow Patterns

Manufacturing cells may be physically arranged into one of the four basic flow patterns.

A *Straight through* flow pattern is easy to understand, follow, schedule, and control. It allows straight, inexpensive handling methods, it is easy access on two sides; easy to expand with a minimum of rearrangement. It avoids congestion at point of delivery and takeaway. It may minimize space requirements when producing large or bulky products and can enable a U-shaped plant layout.

A *U-Shape or Circular* flow pattern automatically returns product, holding fixtures, and mobile handling equipment to cell entrance. The delivery and take-away point are the same; allows convenient material handling to and from the cell. The Workers in the center can assist on another. It is easier to assign multiple operations to an operator. It allows easier line balancing.

The *L-Shape* flow pattern allows fitting lengthy series of operations into limited space; it let's feeding cell(s) start on an aisle and end at point of use. It may allow isolation of dangerous or costly-to-move equipment in the elbow, with savings in implementation cost and/or two directions expansion.

The *Comb or Spine* flow pattern lends itself to two-way flow. It is well suited to cells with highly variable routings. It allows fingers/teeth to be segregated for special requirements [6].

2.4 Assembly Line Balancing

Purpose of assembly line balancing is to minimize number of work stations and reduce delay time in the cycle resulting in higher total productivity. Though primarily a scheduling issue, assembly-line balancing often has implications for layout. At each workstation, work is performed on a product (or assemblies) either by adding parts or by completing assembly operations. The work performed at each station is made up of many bits of work, termed tasks, elements, and work-units. Such tasks are described by motion–time analysis. Generally, they are groupings that cannot be subdivided on the assembly line without paying a penalty in extra motions. The total work to be performed at a workstation is equal to the sum of the tasks assigned to that workstation. The assembly-line balancing problem is one of assigning all tasks to a series of workstations so that each workstation has no more than can be done in the workstation cycle time, and so that the unassigned (that is, idle) time across all workstations is minimized. The problem is complicated by the relationships among tasks imposed by product design and process technologies. This is called the precedence relationship, which specifies the order in which tasks must be performed in the assembly process [7].

3. METHODOLOGY

A systematic approach suggested by Richard Muther in his booklet Simplified Systematic Planning of Manufacturing Cells is adopted to plan the Manufacturing Cell for the MV VCBs.

3.1 Orient the project

The manufacturing cell is required to meet the below mentioned production goals over a period of 10 years, with the following constraints-

i. Floor area limited to 14.2 m x 14.2 m which should include appropriate testing setup along with the manufacturing setup.

ii. Budget / Investment Limited to 1 Hydraulic Worktable & 1 CNC Radial Riveting Machine

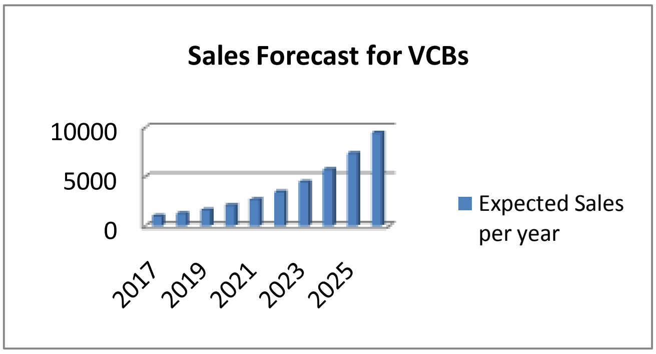

Chart 1: Sales Forecast

3.2 Classify the Parts

For the ease of Material Handling, the components required for MV VCB Assembly are divided into 3 major categories

a. *Standard Components.* The standard components required at the respective workstations would be temporarily stored near the workstations. According to the dimensions of the components, they are stored either crates in the rack near the respective Workstation or in the smaller bins on the Workstation. In case of delicate components that are subject to damage are stored in crates on the rack near the respective workstation with special arrangement of foam to protect them from damage. The components are to be filled at beginning of the each shift.

b. *Non-Standard Components.* The non-standard components are order-specific and hence would be kitted according to every specific order from stores and brought to the Assembly line at the respective workstations using specially designed trolleys.

c. *Hardware.* The Hardware required for assembly activities would be kept in small bins on the respective Workstations and refilled at the beginning of every shift.

3.3 Analyze the process

The Switchgear manufacturing facility is operative for 306 days per year excluding 52 weekly-offs (Sundays) & 7 Public Holidays. It is able to deploy three shifts production a day. The available production time per shift of 8 hours is 420 minutes.

$$Takt\ time = \frac{Net\ Available\ Production\ time}{Demand} \qquad (1)$$

Net Available Production time per year = Production time per shift x Number of shifts operative a day x Number of operative days per year (2)

Therefore,

Net Available Production time per year = 420 x 1 x 306.........1 Shift operative

= 128520 minutes

Net Available Production time per year = 420 x 2 x 306.........2 Shift operative

= 257040 minutes

Net Available Production time per year = 420 x 3 x 306.........3 Shift operative

= 385560 minutes

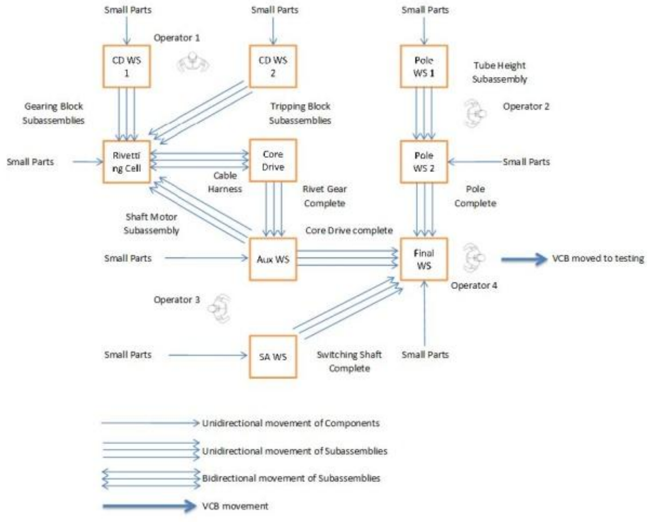

Figure 1: Equipment & Flow Diagram

Table 1: Cycle Time Calculations

Workstation	Activity	Actual time	Frequency of Operation	Total time	Total time per workstation	Round-up time*	Manpower Allocation (Option 1)			Manpower Allocation (Option 2)		
								Cycle Time	Time Loss		Cycle Time	Time Loss
Pole Assembly Workstation 1	VI Placement	0.77	3	2.30	12.19	12.80	Operator 1	28.73	11.11	Operator 1	58.24	8.159
	Pole Head Assembly	0.71	3	2.13								
	Insulator Assembly	0.55	3	1.65								
	Current Link Assembly	1.11	3	3.34								
	Eye bolt Assembly	0.93	3	2.79								
Pole Assembly Workstation 2	Pole Sub Assembly in Pole Shell	1.24	3	3.73	15.17	15.93						
	Pole Support Assembly	3.36	3	10.07								
	Lever Assembly	1.38	1	1.38								
Core Drive Workstation 1	Rivet Plate Subassembly	0.72	1	0.72	4.56	4.79	Operator 2	29.51	10.33			
	Damper Subassembly	1.85	1	1.85								
	Hand Drive Subassembly	1.99	1	1.99								
Core Drive Workstation 2	Crank Shaft Subassembly	1.71	1	1.71	3.44	3.61						
	Plate & Dovel Subassembly	0.80	1	0.80								
	Closing Latch Stop Subassembly	0.93	1	0.93								
Core Drive Workstation 3	Cable Harness Coredrive	3.81	1	3.81	3.81	4.00						
Rivetting Cell	Gearing Block rivetting	8.18	1	8.18	16.30	17.12						
	Tripping Block rivetting	8.12	1	8.12								
Auxiliary Assembly Workstation	Shaft Motor Subassembly	2.34	1	2.34	14.44	15.17	Operator 3	26.56	13.28	Operator 2	66.4	0
	Small Gear Subassembly	1.18	1	1.18								
	Crank Assembly	1.93	1	1.93								
	Bearing Assembly	1.40	1	1.40								
	Spring Charged Indicator Assembly	1.22	1	1.22								
	Solenoid Assembly	3.08	1	3.08								
	Motor Assembly	3.30	1	3.30								
Switching-Shaft Assembly	Compression Spring Assembly	5.67	1	5.67	10.85	11.39						
	Opening Spring Subassembly	2.48	1	2.48								
	Opening Spring & bearing Assembly	2.70	1	2.70								
Final Assembly Workstation	Housing Panel Assembly	0.93	1	0.93	37.95	39.84	Operator 4	39.84	0.00			
	Pole Assembly	3.83	1	3.83								
	Tail Hook Assembly	1.63	1	1.63								
	Bearing Plate Assembly	3.58	1	3.58								
	Crank Shaft Assembly	5.47	1	5.47								
	Drive placement	2.23	1	2.23								
	Opening Spring Placement	1.12	1	1.12								
	Coupling Crank Shaft Assembly	4.85	1	4.85								
	Damper Assembly	1.09	1	1.09								
	Closing Spring Assembly	1.98	1	1.98								
	Cable Harness Assembly	5.23	1	5.23								
	2nd release cpl (optional)	3.32	1	3.32								
	IP-plate (optional)	1.85	1	1.85								
	Labels	0.84	1	0.84								

*Round-up time is actual time + 5% contingency rounded up to next interger.

3.4 Couple into Cell Plans

Based on the product data and the available space for the manufacturing cell, the different cell plans proposed were as follows,

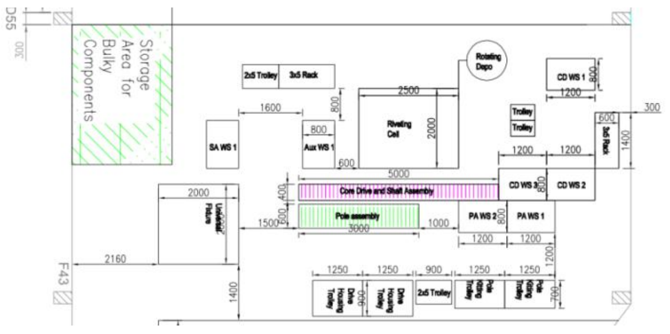

Figure 2: Proposal 1

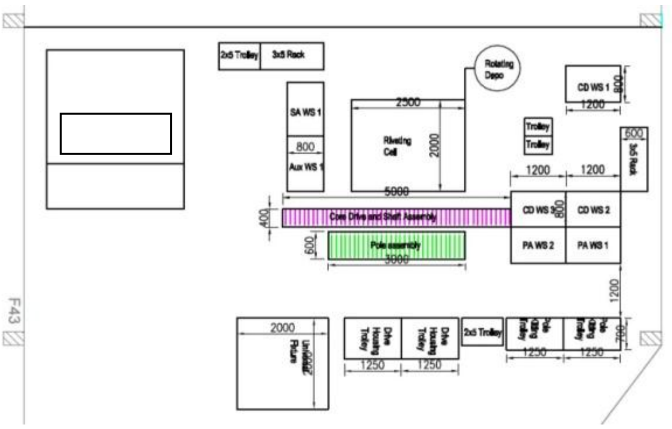

Figure 3: Proposal 2

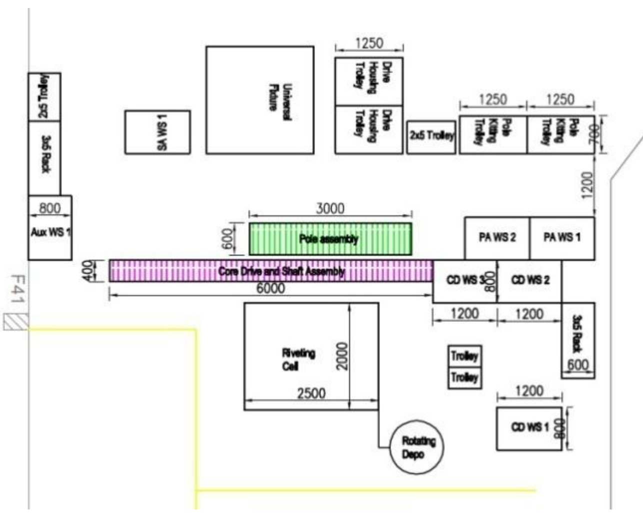

Figure 4: Proposal 3

3.5 Select the Best Plan

The selection of the best plan typically depends upon comparisons of cost and intangible factors. Since the cost of the alternative plans fall within a narrow range; as the infrastructure remains almost similar, the final selection is based on intangible factors. A weighted-factor method is the most effective way to make selections based upon intangible factors [6].

Table 2: Weighted Factor Analysis

Factors	Factor Weight	Proposal 1		Proposal 2		Proposal 3	
		Rating	Score	Rating	Score	Rating	Score
Flexibility	5	4	20	3	15	2	10
Response time to changing production demand	5	4	20	2	10	1	5
Ease of supervision	2	2	4	2	4	3	6
Ease of material handling	4	3	12	3	12	3	12
Utilization of floor space	4	3	12	2	8	4	16
Acceptance by key employees	3	3	9	3	9	3	9
Effect on Quality	5	4	20	4	20	4	20
Modifications required in future for increased production	4	4	16	2	8	1	4
Overall score			113		86		82

Refer table 2 for the intangible factors considered while selecting the best plan along with the appropriate weights. The weights to the factors and the corresponding ratings were allotted on a scale of 5.

$$Score = Factor\ Weight \times Rating \quad (3)$$

Proposal 1 with the highest overall score was selected for implementation.

3.6 Detail and implement the plan

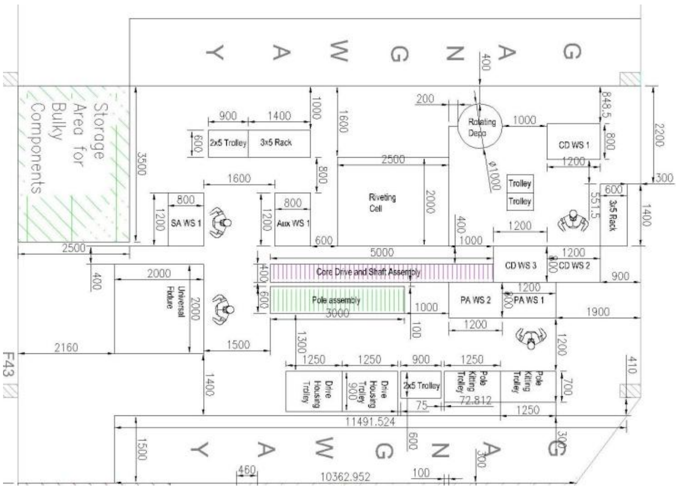

Figure 5: Detailed Layout with normal operator positions

4. RESULTS & DISCUSSIONS

The assembly line flow pattern designed is a "Straight Thru" type. The constraint of area allotted for the new MV VCB favored this particular flow pattern. The assembly activities for Core Drive & Pole start simultaneously on two sides of the layout. Conveyors help the Sub Assemblies reach their destination with a buffer temporary storage. As the Subassemblies move further on the assembly line supporting activities are carried out on Auxiliary Workstation and Switch-shaft assembly Workstation. The Subassemblies are delivered at the Final assembly Workstation through conveyors to carry out the Assembly of all the preassemblies done. Gangways on both sides of layout aid men and material movement from the start to the end of the assembly line.

The following observations have been recorded after through calculations of cycle time for manufacturing MV VCB. It is observed that the cycle time of activities to be carried over Hydraulic Worktable (Final Assembly Workstation) is about 34 minutes. Due to investment constraints only 1 Hydraulic Worktable would be installed at site. This limits the minimum possible cycle time to 34 minutes. Studies imply that to achieve this minimum cycle time of 34 minutes; work content per VCB is to be distributed among 4 operators. During allocation of work to various operators, idle times are observed for which Manufacturer has no alternative but to bear it. Further, it can be analyzed that the actual idle times are reduced to some extent (0.5 to 1 min approx.) due to non-value adding travel of operators from one workstation to another (except the Final Assembly Workstation) and material handling which would in-turn help maintain a synchronous work cycle.

5. CONCLUSIONS

Facility design is crucial issue for production related decisions. The choice of type of facility layout to adopt can have a significant impact on the long-term success of a firm. The efficiency and productivity depends on the type of manufacturing layout is being used for production of goods and services. Not only efficiency is increased directly but indirectly good facility layout also contributes to efficiency by reducing accidents, hazards, by increasing easiness and convenience. Most importantly a better facility design allows smooth function off manufacturing. For implementing lean production, it is important to set machines in the right place to have less transportation waste. A major issue to be addressed in facility layout decisions in manufacturing is: How flexible should the layout be in order to adjust to future changes in product demand and product mix.

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