Saving Time & Money:

A Case Study of a Texas Utility's Experience Utilizing a **Customized Factory-Built Substation** Approach for its Standard Outdoor Open-Air Distribution Substation

Prepared For

TSDOS TRANSMISSION AND SUBSTATION DESIGN AND OPERATION SYMPOSIUM

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DIS-TRAN Packaged Substations

DIS-TRAN PACKAGED SUBSTATIONS

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1.0 ABSTRACT

This paper will demonstrate the process one Texas-based investor-owned utility, Texas-New Mexico Power Co. (TNMP), utilized to convert its standard outdoor, open-air distribution substation from an on-site constructed facility to a factory-built product, customized to its unique requirements. The paper will address the project objectives established by the utility at the outset in order to clearly define success. The paper will describe, in detail, the collaborative approach used by the utility and the substation manufacturer, DIS-TRAN Packaged Substations (DTPS), from concept phase through the detailed design phase of the project. This collaborative approach ensured all key stakeholders' concerns were addressed not only in the design, but also in the final on-site assembly of the substation modules. This paper will highlight and explain how the substation manufacturer's design team utilized 3D modeling tools during the interactive design process to pre-diagnose and resolve numerous "last mile" constraints, such as shipping restrictions and site rigging availability. The case study will conclude with an itemized listing detailed cost assessment, the impact this factory-built substations approach had on the substation's completion schedule, lessons learned, and overall successful project outcome.

2.0 INTRODUCTION

As Texas-New Mexico Power strives to accommodate its growing customers' needs, the company reviews its current substations, evaluates plans to increase the voltage of its substations, and strategically lays the ground work to expand its electrical grid. Though voltage up-grades are necessary and must happen in a timely manner, quality and safety is still TNMP's utmost concern [1].

2.1 Texas-New Mexico Power (TNMP) Background | Service Area

Figure 2-1: TNMP Service Area Map*

*Map provided by TNMP on July 5, 2016

Founded in 1935, TNMP is an electricity transmission and distribution service provider, providing electric service to customers on behalf of competitive retail providers within the Electrical Reliability Council of Texas (ERCOT) power system. The company uses more than 9,000 miles of transmission and distribution lines to provide electricity to more than 243,000 homes and businesses in more than 70 communities from

small rural farming areas to the suburbs of Houston and Dallas-Fort Worth. TNMP is also a power provider for critical international petroleum customers along the Texas Gulf Coast. While its formal name is Texas-New Mexico Power Co., it serves users solely in the state of Texas. TNMP is a subsidiary of Public Service Company of New Mexico (PNM). While PNM is headquartered in Albuquerque, New Mexico, TNMP's main office is in Lewisville, Texas. TNMP employees more than 375 people in more than 20 communities throughout Texas [2]. It takes great pride in not only delivering reliable power and quality service to its customers with accurate meter readings and prompt response to power outages, but also giving back to its valued employs and community. TNMP employees and retirees can request a contribution of as much as $500 a year on behalf of a Texas nonprofit organization with which he or she volunteers. In addition, in 2015, TNMP awarded $30,000 in grants to Texas nonprofits, municipalities, and school districts. TNMP success, in return, benefits the community it serves [3].

2.2 TNMP's Need for Growth

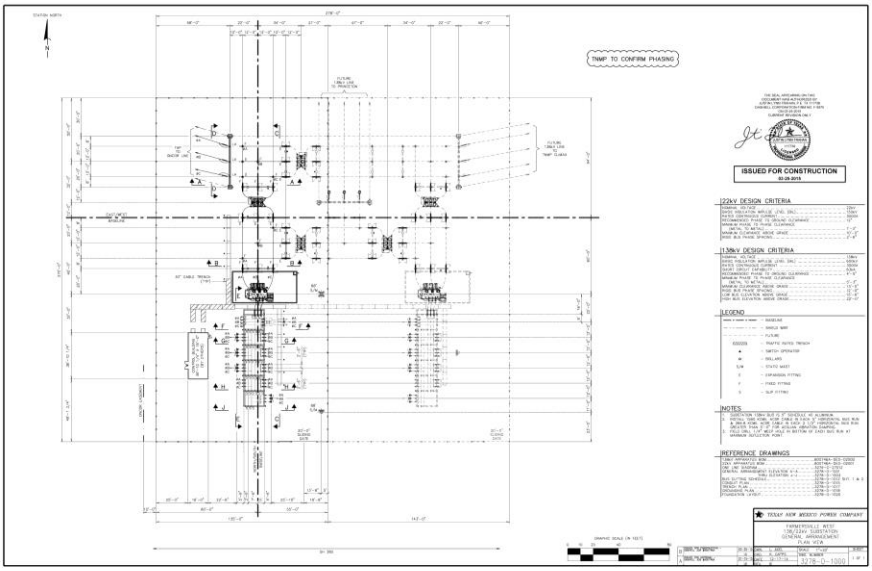
Due to significant retail customer growth, TNMP is in the process of converting a large part of its system in west Texas from 69kV to 138kV. TNMP's standard substation consists of a six breaker ring bus which accommodates a transmission bypass and four other connections. Those connections vary between capacitor banks, transmission connections, and distribution bays.

Originally, TNMP planned to rebuild its existing Flat Top Substation. However, after review, the company decided a large footprint substation would better address its oil and gas customers' needs in the Permian Basin. Chris Gerety, Director of Engineering and Land Services for TNMP, says the big voltage conversion needs to happen. "Once we saw how much activity was out there we decided it was better to overbuild and have our standard substation and distribution bay verses trying to retrofit a brownfield site with some sort of custom design," he explains [1].

2.3 Project Needs

TNMP's project called for a 25kV distribution bay consisting of six bays and five 25kV distribution circuit breakers. With quality and safety as its utmost concern, TNMP is insistent its substations are uniform. "We put a lot of time and effort into designing the substation from a reliability stand point. We are very redundant and very robust. So we want to continue that effort and maintain our design," says Gerety [1]. A standard substation improves safety by ensuring TNMP's workforce is familiar with its facilities and equipment. Gerety continues, "From a safety perspective, that was really one of the biggest driving forces to have a similar design. This way our field folks have a clear understanding of how the site operates, making their job that much easier and safer." [1]

Figure 2-2: Page 1 of TNMP's Original Quote Drawings



3.0 THE NEED FOR AN ALTERNATIVE APPROACH

"When a company says to you, 'By the way, we've looked at your box and we think we can actually build it in the factory and ship it to you already assembled, you get excited.'"

– Chris Gerety, Director of Engineering & Land Services, Texas-New Mexico Power

3.1 Project Location Hurdles

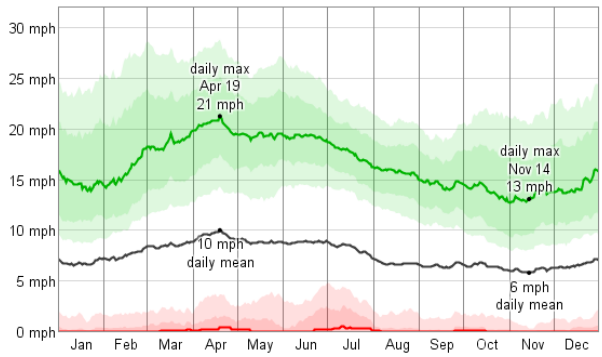
The location of TNMP's new, large footprint substation is remote and located more than 20 miles south of the small town of Pecos, Texas. "It's out in the middle of nowhere," describes Joe Sandifer, safety inspector for TechServ. Sandifer worked on-site for TNMP's project [4]. Managing remote resources, as in this case, is extremely difficult. "You don't just have a Lowe's down the road where you can pick up construction materials. You don't have any local large electric supply houses that keep large inventory of things. You have to

Figure 3-1: Project Location On Map

drive three to four hours away round trip to find the things you need if you are short supplies," explains Gerety. [1]

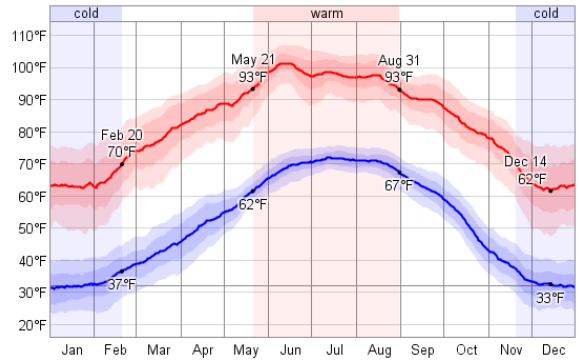
In west Texas there are weather constraints as well. Wind is the biggest hurdle. In Pacos, the average daily maximum wind speed is 21mph [5]. The dryness in the area mixed with high winds leads to dust storms. Having worked in the industry for more than 20 years building substations across the country, Duke Taylor, DIS-TRAN Packaged Substations' Factory-Built Substation Manager, is familiar with the project's location. He also specifically worked on TNMP's project. "Where this project was erected, the problem was dust. They had bad dust storms going on," says Taylor [6].

Table 3-1: Wind Speed Chart



www.weatherspark.com

Table 3-2: Temperature Chart



www.weatherspark.com

Gerety says temperatures are also a problem [1]. The warm season lasts from May 21 to August 31 with an average daily high temperature above 93 degrees. The cold season lasts from November 20 to February 20 with the average daily high temperature below 70 degrees [5]. This narrows the time frame of comfortable building conditions. "Ultimately because there are adverse weather conditions, if [crews] are having to do construction techniques that can't be performed in those difficult weather conditions you don't have any choice but to just have everyone stand down and be sitting," says Gerety [1].

3.2 Construction Quality & Safety Management

With TNMP's traditional substation construction methods, a crew would build the high side of a substation and then move on to the low side. Gerety says he prefers to manage one crew at time and avoids having multiple crews on site. This inevitably leads to a "waiting period". However, with a factory-built substation, "The distribution side just showed up built and it basically just went into service," explains Gerety [1]. The indoor construction environment with a factory-built substation reduces the risks of accidents and related worker reliabilities. By relocating much of the work to the controlled safety conditions of a factory environment, much of the serious safety risks inherent in an electrified

substation are mitigated [7]. TNMP's distribution bay design leaves little room for contractors to be elevated and assemble bus in the field. Crews would need to work off of ladders. Standard machinery would not fit in the interior sections of the structure. Working out of a factory, and on a concrete slab, DIS-TRAN Packaged Substations was able to use scaffolding in the tight construction areas of the bays, making assembly both faster and safer [6].

Photo 3-1: Project Assembly Inside Factory Utilizing Scaffolding

TNMP highly values both safety and quality. Previously, TNMP built its distribution bays through its traditional supply chain methods. The electric company has its own corporate strategic supplier that supplies individual building materials; is the various lots of materials are then drop shipped to the site. The supplies are collected until all of the pieces arrive. Then, erection of the project can begin [1]. Building off site however, ensures controlled construction quality management. Rather than being delivered to a remote location without much protection from adverse weather conditions, materials are delivered to the plant location and are safely secured and stored in a manufacturer's warehouse. This prevents damage or deterioration from moisture and other elements [7]. Those elements can also affect the quality of aluminum welding. West Texas' dry air, windy conditions, and dust can potentially interfere with a project's quality control goals [8].

Structurally, factory-built substations must be designed and built to withstand the rigors of transportation. Travis Eaglin is a design engineer technician for DIS-TRAN Packaged Substations. Eaglin contributed to the design of TNMP's project. "We had to design the structure so that it could basically survive a seismic event, says Eaglin. "We are talking about [a substation] running down the road, hitting pot holes and curbs, going more than 60 miles per hour," he continues [9]. Modular buildings that are built to withstand the same conditions are typically stronger than conventional construction [7].

Photo 3-2: Project Being Shipped

3.3 Cost & Time Savings

TNMP's traditional delivery processes are extremely tedious. "[Our crews in] the field tear apart all the pallets and packages, and say, 'Oh we have everything, except these 100 things.' And then we go back and forth with the field saying, 'We've reordered. Do you have it?'" says Gerety. This process can take weeks and eats into construction time. Gerety further explains, "For us, we are always being pushed at a corporate level to get dollars spent and be back in-service as quickly as possible." [1] DIS-TRAN Packaged Substations assured TNMP its distribution bay would show up on site, built, and ready to go in-service.

While the design stage of a factory-built substation may not take less time than a standard substation, the time savings for the customer is in the field [8]. By being constructed in a controlled environment, there are more tools and options to perform the work more precisely, at lower cost, and faster. A contractor will have less to assemble in the field. Also, expensive field equipment may not be necessary. Eaglin typically references a popular children's toy when describing factory-built substations, "They're ready to go. You basically bolt everything into place like Legos you put together." [9] Leaving the erection phase of a substation project quick. This means less hours "on-the-clock" for contractors and less field and travel expenses. "You add up the fact that you have to pay [contractors] per diem every day, you have to pay for a hotel, all kinds of different things you have to pay for if someone is in the field instead of working in a factory," says Gerety [1].

With electric companies utilizing factory-built substations and paying contractors less per project, there could be the assumption contracting companies would be against this new method and use of technology. However, Sandifer argues he prefers erecting factory-built substations. "It does not mean a smaller paycheck. It just means we can finish one project and move on to the next," he says [4]. Factory-built substations allow electric companies and their contractor partners to complete more projects year-to-year and provide better service to their customers.

4.0 DESIGN INTEGRATIONS

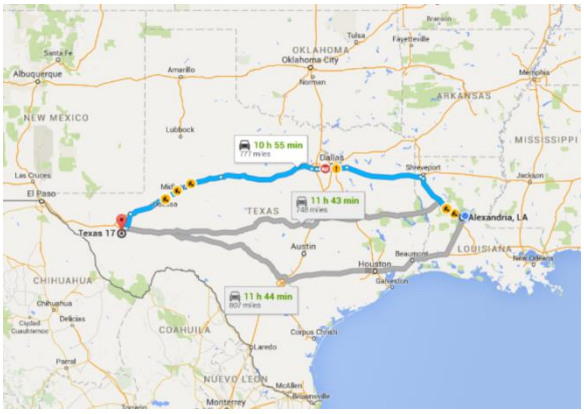
"We had to stick to TNMP's main design. Minor details around them are what we tweaked in order to accommodate shipping constraints."

- David Perry, Project Manager, DIS-TRAN Packaged Substations

4.1 The Communication Process

DIS-TRAN Packaged Substations goal was clear: turn an electric company's standard distribution bay structure into a factory-built substation without changing its design. TNMP wanted its new substation to have the same number of breakers, switches, and bays as its standard substation. However, there was a process in reaching this understanding. David Perry was DIS-TRAN Packaged Substations' project manager assigned to the project. It is his responsibility to understand the customer's needs, interpret the information they provide, and then communicate those project requirements to DTPS' engineers. In return, he relays the engineers' concepts and drawings back to the customer. "The hardest part wasn't so much between us and the customer. The customer trusted us. We knew what they wanted," says Perry. The big challenge in the communication process was juggling the *many* different individuals involved in the project. TNMP had its own project managers as well as its own engineers. Perry also needed to be the point-of-contact between TNMP's subcontractors, and the trucking company used to deliver the substation. Constantly maintaining open communication throughout the entire project is crucial. "A FBS [factory-built substation] requires you to be more involved than you have to be during a typical substation," says Perry. Traditionally, project managers need only to talk to the customer, and project coordinators and engineers within their own company. Factory-built substations require additional details throughout the design development. Shipping requirements and restrictions, for example, play a large component in the design process [10].

Figure 4-1: Shipping Route

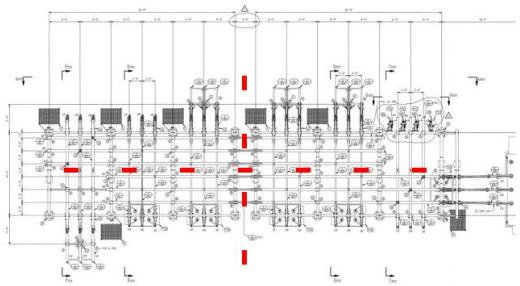


Perry stayed in constant communication with the trucking company selected to ship the completed substation. This communication was crucial in ensuring a substation this large would be able to ship safely, and legally, to TNMP's desired location in west Texas. Perry recalls phone conversations occurring almost every other day. Each new engineering and design drawing needed to be sent over to the transporter for review. The trucking company would then let Perry know, based on the design, if the substation would fit on the truck safely and what type of permits would be required. "As you ship something this big across different states, everything changes," explains Perry [10]. The state of Louisiana has a shipping height limit of 13'6" [11]. The state required the trucking company to obtain special permits in order to ship the distribution bay. However, once the shipment entered the state of Texas, special permits were not required [10].

4.2 Balancing Customer Needs & Shipping Requirements

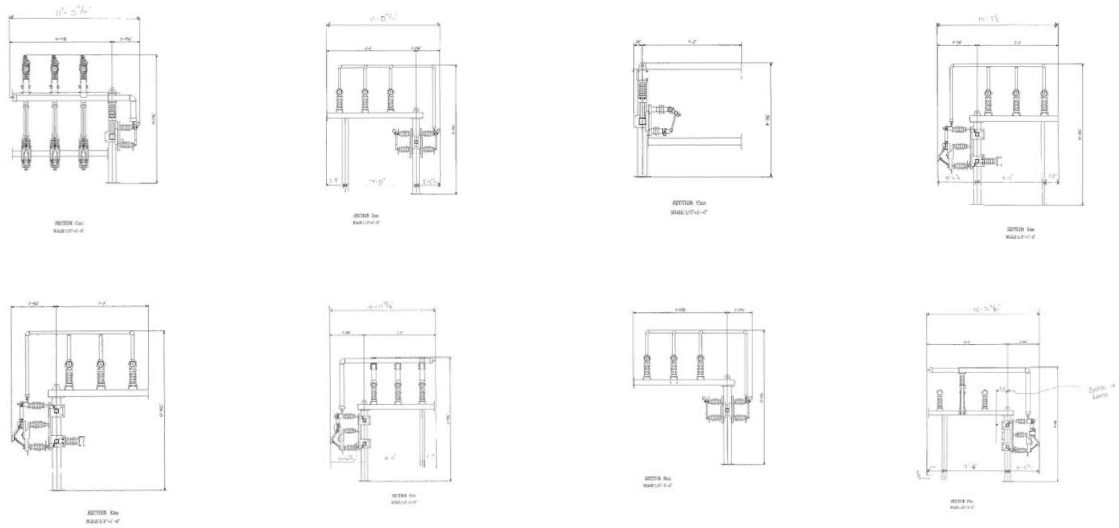
Though the state of Louisiana does not restrict the length of oversize shipments, it does require various degrees of pilot and escort cars depending on the width and length of the cargo. On four lane roads, anything 12'-14' wide requires a front escort car. Over 90' in length requires one rear escort car. Over 125' requires a state police escort [11]. The varying requirements can change the overall cost of shipping significantly. Frank Camus, Vice President of Engineering and Design for DIS-TRAN Packaged Substations, played an integral role in establishing the design intention for TNMP's distribution bay by guiding the team to begin with the end in mind. Camus explains, "Since nearly anything is possible from a design perspective, it is really important for us to determine what the customer places the most value on since there are trade-offs involved. In order to strike the optimum solution for the customer, we must balance the impact on transportation cost of shipping larger modules with the field cost impact of shipping smaller modules" [8]. DTPS presented several design and shipping possibilities to TNMP in effort to optimize the cost-benefit of a factory-built substation. In the end, TNMP opted for a divided substation that would be shipped in four segments.

Figure 4-2: Split Quadrant Design Concept



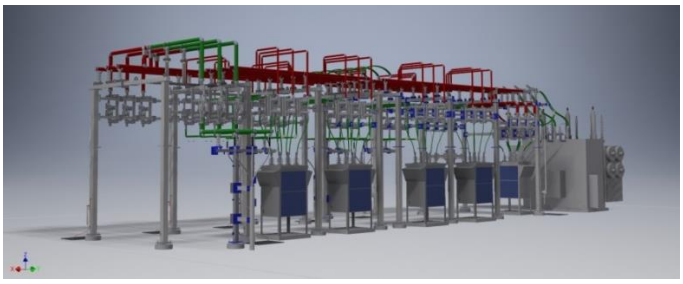
"There was probably five or six of us sitting around in a room, figuring out how we are going to segment [the substation]," recalls Eric Veuleman, DIS-TRAN Packaged Substations' Engineering Manager. DTPS needed to maintain TNMP's dimensional footprint. There was not any flexibility on the layout design. Scaling the structure down was not an option. "All of [TNMP's] overall heights were set, their bay widths, their spacing," explains Veuleman [12]. Taking into consideration shipping requirements and cost, DIS-TRAN Packaged Substations' engineering and design team decided to essentially halve TNMP's distribution structure. This was in effort to keep shipments 40' or less [13]. The standard width of TNMP's distribution bay is also wider than state law allows. Therefore, the design also needed to be quartered, separating the substation into four parts (four modules) [9]. Figure 4-3 shows drawings sent to the trucking company.

Figure 4-3: Substation Pre-Assembled Components



4.3 Dimensions of Accuracy to Design

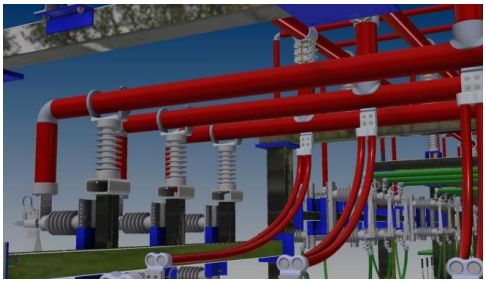
Figure 4-4: 3D Drawing of TNMP's Factory-Built Distribution Bay



It took the DIS-TRAN Packaged Substations' engineering and design team about two weeks to modify TNMP's standard design and convert it into a functional, shippable, factory-built substation. Though the design phase of the project did not necessarily take any less time than when creating a traditional substation, the 3D modeling aspect of the project ensured the substation's components and measurements would be exact. The split substation's connections would be able to line up. In return, this would speed along construction and virtually eliminate assembly problems in the field [12].

3D modeling opens up new avenues of efficient substation construction. 3D substation models start with the same information used in 2D drawings, then add volumetric and connective data by joining the faces, edges and points of flat surfaces together. The result is a complete representation of a three-dimensional object or structure that is an order of magnitude more accurate and actionable than 2D drawings.

Figure 4-5: 3D Drawing of Project's Pre-Fabricated Bus (PFB)



The design process becomes increasingly reliable because it is less prone to human error while offering an improved ability for users to perform integrity checks. The technology incorporates the ability to analyze the impact of environmental and physical forces acting upon the structure. Though this distribution bay would not be erected in a seismic area, DTPS' engineering and design team accounted for the substation withstanding a seismic event. The team calculated loads to simulate a high seismic event and modeled the seismic conditions in its finite element structural analysis software package, STAAD.PRO. The seismic loadings applied simultaneously with a 70 MPH wind load were intended to simulate the transit loads the structure was expected to be subjected to. These loading conditions could not simply be applied to the structure in its final as-installed condition but rather the structure had to be modeled in each as-shipped module condition. This ensured DTPS its factory-built distribution bay would be strong enough to survive the rigors of traveling down the highway.

5.0 CONSTRUCTION & ASSEMBLY

"If the design team could do it, we could build it."

– Duke Taylor, Factory-Built Substation Manager, DIS-TRAN Packaged Substations

5.1 Factory-Built Logistics

With the design complete, and the substations' steel and parts already ordered and delivered, Duke Taylor and the rest of his team at DIS-TRAN Packaged Substations' Project Support Service Center were ready to start building TNMP's factory-built distribution bay. Traditional substations of this size are typically assembled one piece at a time in the field on top of previously constructed foundations. However, because this substation would first be erected in a factory on a concrete floor, the DTPS team needed to develop a solution on how to build a substation without a foundation. A steel rail system was created to temporarily mount the substation on the factory floor and hold base plates and columns in place during construction. The entire system is adjustable. It functions much like a bed frame that can expand or contract depending on the size of mattress. "Without it, we wouldn't have been able to build it," says Taylor [6].

Because the substation would initially be built without a concrete foundation and was designed to be shipped in partial assemblies, support steel needed to be put in place to hold the structure safely and securely during shipping. As shown in Photo 5-1, the steel supports were in place throughout the factory-built construction phase. The design team fabricated step-by-step erection drawings showing the contractors how and when in the erection process to remove each steel support [8].

Photo 5-1: Steel Rail System and Supports

Taylor and his team were able to factory build TNMP's distribution bay in ten days. Though Taylor says the project could have been completed in half that time if it were not for a problem with the switches provided to DIS-TRAN Packaged Substations by a switch manufacturer [6]. The switch mountings did not match the vendor-provided drawings. Once mounted, each switch was a few inches short. To avoid any more time delays, Taylor drilled new holes, raising the switches to match up with the bus [14]. The end result was an aligned substation ready to be shipped to its site location.

5.2 Delivery & Installation

TNMP's factory-built substation was delivered to its site just one day later. Taylor along with Joe Sandifer, the contractor for the project, were on-site as the four trucks pulled up carrying quadrants of the distribution bay. "I had never seen anything like that before. We always have had to do everything on the job site. But it was perfect," recalls Sandifer [4]. It took about three and a half hours to unload each quadrant from the trucks. Installation would occur in a few weeks. Due to site issues, TNMP was unable to begin its foundation work during the factory construction phase of the project. When the factory-built substation arrived on-site, the foundation work was still not complete.

Photo 5-2: Substation Delivery and Unloading

Photo 5-3: Substation Assembly

DIS-TRAN Packaged Substation waited for a call from TechServ, TNMP's contractor, to be notified when assembly would begin. The plan was for a DTPS' team member to be on-site during substation construction. This was TNMP's first factory-built substation and DTPS wanted to be present in case any assembly questions arose. However, when TechServ called, it was not to give DTPS an assembly date. "I was kind of amazed. We got a phone call saying, 'We put it together.

It went together fine,'" says Taylor [6]. Sandifer says assembly was simple. His team was able to erect the distribution bay in just one day. "When we put the quadrants together, every bolt hole matched up. We had no problems at all," recalls Sandifer [4]. Taylor credits the substations' precision and overall project's success to DTPS' use of 3D modeling [6].

6.0 LESSONS LEARNED

"That's the learning experience. Things we didn't account for but should have."

- Frank Camus, Vice President of Engineering & Design, DIS-TRAN Packaged Substations

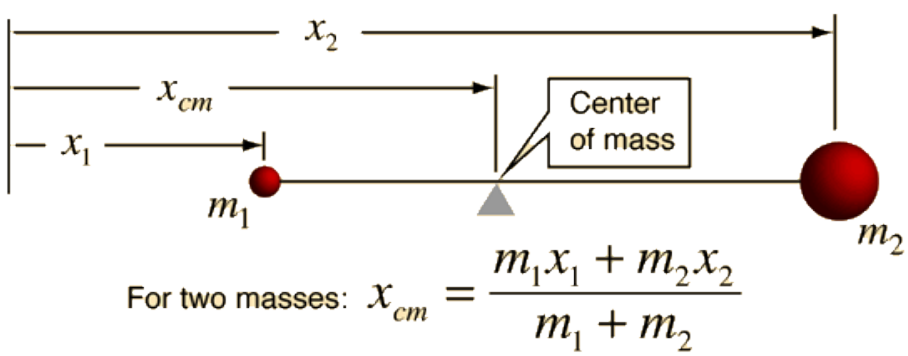
6.1 Pre-Planning an "Exit Strategy"

A tremendous amount of thought went into the design and construction process of creating this factory-built substation. However, when it came time to move the assembled quadrants of the distribution bay out of the factory, DIS-TRAN Packaged Substations ran into a couple problems.

Photo 6-1: Elevating the Substations' Quadrants for Shipping

First, DTPS' engineers factored the center of gravity for the substation in its entirety. That calculation became irrelevant though as soon as the substation was split into quadrants. A new center of gravity needed to be formulated and the structures steel lifting-eyes had to be relocated [14]. Not accounting for the "new" center of gravity once the substation was split, set DIS-TRAN Packaged Substations back a day. Rather than taking only one day to load the shipping trucks, it took two [6].

Figure 6-1: Center of Gravity Formula



Secondly, DTPS' engineers and designers did not account for its factory doors' clearance. "We thought we had door measurements. Obviously we didn't. Or, someone didn't verify those measurements," Eaglin says with a laugh [9]. The factory doors obstructed the substations' columns. DTPS workers had to maneuver the substation to clear the doors and the tight turn outside of the factory doors by unloading and reloading the substation while pivoting the trucks and then repeating the process [6]. "This one pushed the limits. If it was two inches taller it wouldn't have made it. We would have had to take the door down to the Project Support Services facility," says Perry [10].

6.2 Shipping: The Lower, The Better

When working with the trucking company, Perry specifically asked for four low boy trucks. This would ensure better clearance and in effort to comply with state highway height regulations, all four trucks would take the same route to the site location. However, the trucking company was unable to supply DIS-TRAN Packaged Substations with the fourth low boy, and instead, provided a step deck [14]. En route to the site, a quadrant of the substation being carried by the step deck hit a tree and a section of transfer bus was damaged. Because of DIS-TRAN Packaged Substations use of 3D modeling, the pre-fabricated bus was able to be recreated, shipped and delivered in little time. However the need for low boy trucks when transporting factory-built substations was made apparent. "If we had the four low boys we wouldn't have had a problem," says Perry. The struggle came when working with the trucking company. As a project manager, Perry wanted to trust the company he hired to do its job. He says in the future, he will be able to speak from experience, and stress all shipping trucks be the same height and ride low to the ground [10].

7.0 ANALYSIS

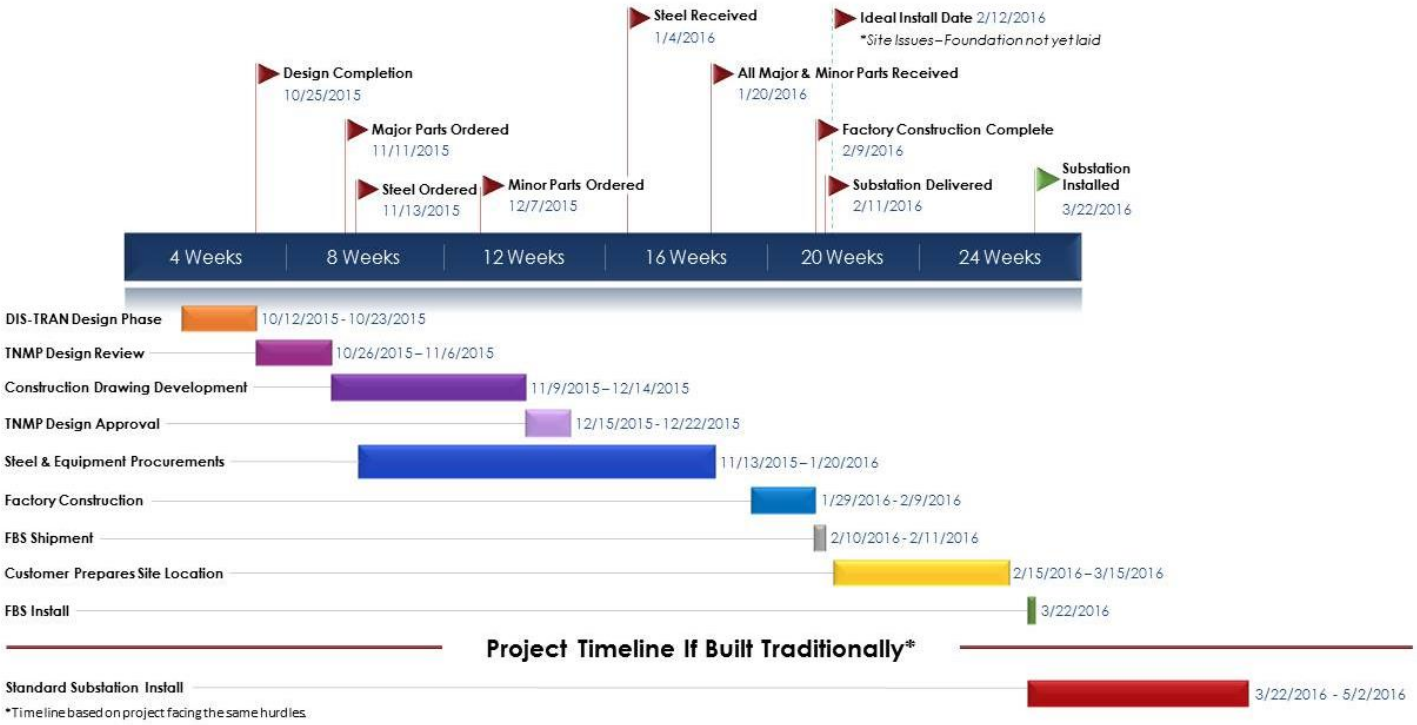
"We had a really positive experience and the project was very favorable on our side."

- Chris Gerety, Director of Engineering & Land Services, Texas-New Mexico Power

7.1 Schedule

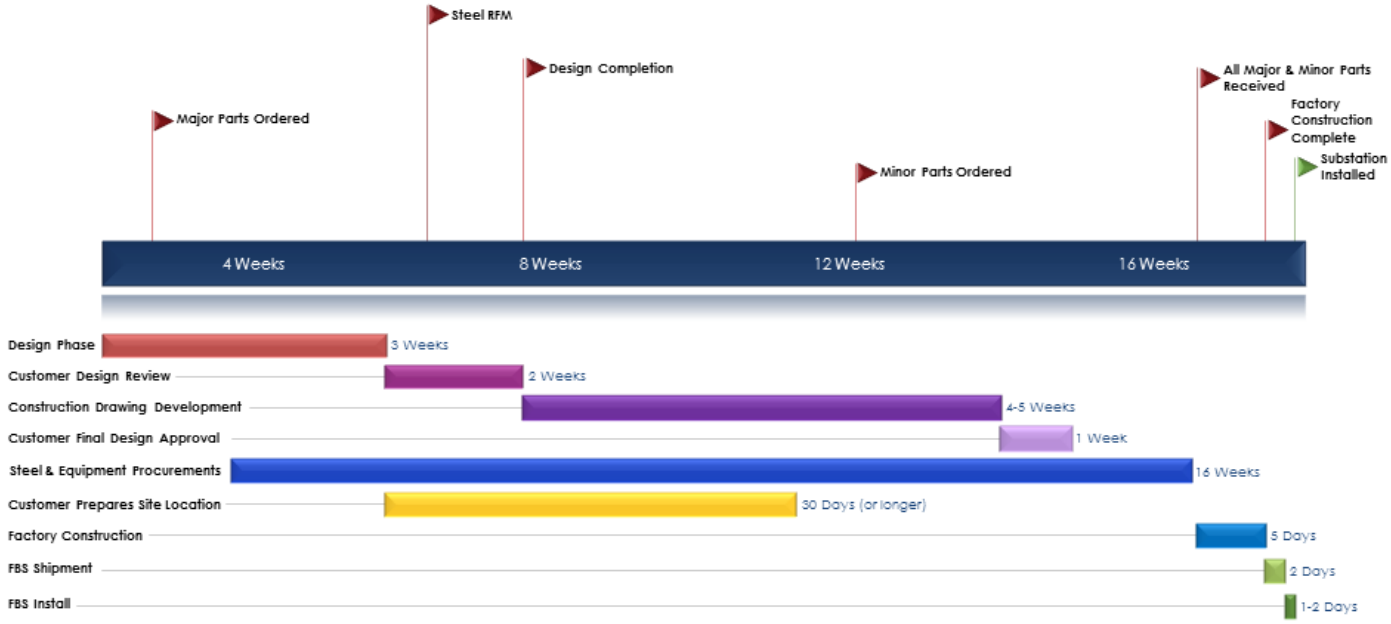
TNMP's factory-built substation was erected in just one field day's work. Sandifer says, based on his experience, a substation that size erected solely in the field would typically take weeks to construct. "You have to put it all together and then you need a welder there to do all the welding on the bus. Plus you have to put on the insulators and the switches," explains Sandifer [4]. Figure 7-1 shows TNMP's factory-built substation's timeline and gives a comparison of the project if traditionally built.

Figure 7-1: Project Timeline Comparison



Ideally, the benefit of having a factory-built substation is maximized when using parallel construction. Meaning, while substation is being assembled in the factory, the normal three week process of digging, pouring, and curing the substation's foundation is taking place [10]. This would allow for the factory-built substation to be erected the following day, or even the day-of, shipment.

Figure 7-2: Ideal FBS Timeline



7.2 Cost

DIS-TRAN Packaged Substations' total contract amount was slightly greater than $250,000. This total included factory labor and construction. The average weekly cost of a six person field construction crew with per diem and hotel is $18,000 [4]. Gerety says having TNMP's distribution bay factory-built possibly shaved two to three months off their total construction time [1]. Based on Gerety's assessment, the elimination of material shortages, eradication of alignment issues, and the removal of weather delays, DTPS conservatively estimates TNMP saw a construction labor savings of $60,000 to $80,000.

The time-savings of factory-built substations also allow for the project to get online more quickly. The sooner a substation gets online, the sooner revenue can be generated.

8.0 CONCLUSION

Both DIS-TRAN Packaged Substations and TNMP are pleased with the projects' outcome. Its factory-built substation significantly reduced on-site construction time and expense. The factory setting not only helped control costs and schedules by eliminating environmental disruptions, but also offered more tools and options to perform work more precisely and safely. Applying the factory-built approach to this project allowed TNMP to put in service its standard-design distribution structure, utilizing all its standard equipment much more quickly and at an overall lower cost than it would have if utilizing traditional field construction practices.

Photos 8-1: Connected Substations' Quadrants

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