Estimated Quantitative Cost Range Analysis for Installation of Phasor Measurement Units (PMUs) in Ontario's Power System

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Executive Summary:

During the IESO stakeholder engagement webinar sessions[1], a number of stakeholders requested that the IESO provide additional details on the expected costs associated with complying with the proposed new requirements for installing Phasor Measurement Units (PMUs). In response the IESO agreed to provide indicative generic cost ranges for the deployment of PMUs. Accordingly, this document provides high level estimates[2] of the likely cost ranges that transmitters or generators may incur for installation of PMUs in Ontario's power system. The cost estimates are identified based on online research conducted by the IESO, inputs based on PMU vendors'/consultants' experiences, and research and feedback from selected Market Participants (MPs)[3,4].

Based on the main factors elaborated below, the total upfront cost per PMU on average may range between $50,000 and $300,000 for transmitters (transmission stations). Whereas, considering the greater flexibility available to generators (generation stations) in terms of design and functionality of the equipment needing to be installed, an average total upfront cost per PMU for generators may range between $25,000 and $200,000.

These costs may vary within these identified ranges for various applicable MPs depending upon their unique conditions and infrastructure needs on a case to case basis, including factors such as the choice of whether to adopt various strategies based on use of Phasor Data Concentrators (PDCs), telecommunication infrastructure requirements, crew training needs, software application costs, and existing physical substation constraints. This information can serve as a guideline for the likely range of expected costs for deployment of PMUs.

Main factors considered for determination of PMU installation costs

Communications (C), security (S), labor (L) and equipment (E) are the key factors/drivers associated with the PMU installation costs (IC). By estimating a cost range for each factor first for transmitters followed by generators, the overall cost of installing PMUs is calculated based on the following formula:

$$IC = C + S + L + E$$

Communications (C):

In absence of a high-speed telecommunication network, there is a need for installing or upgrading telecom circuit bandwidth to accommodate additional PMU traffic upon further specific assessment of the existing circuit's capabilities. These installation and upgrade costs are identified as the most significant contributors to the overall PMU acquisition and installation costs. However, they are the hardest to estimate due to numerous existing variables unique to each MP. Synchrophasor communication costs can be derived from the following formula:

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[1] Active Engagements. Retrieved from https://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Updates-to-IESO-Monitoring-Requirements-Phasor-Data

[2] All estimates are in Canadian Dollars (CAD)

[3] Factors Affecting PMU Installation Costs. Retrieved from US Department of Energy: https://www.energy.gov/oe/downloads/factors-affecting-pmu-installation-costs-october-2014

[4] The Value Proposition for Synchrophasor Technology. Retrieved from NAPSI: https://www.naspi.org/node/356

C = TN + ED

where ***TN*** is the cost associated with telecommunication networks and components used for linking sites to one another such as repeaters, towers, etc. and ***ED*** is the costs associated with procurement and installation of electric devices used at PMU sites and control centres. Some of the cost calculations associated with these two factors are as follows based on the conducted research and feedback from MPs.

- Install new/upgrade Phasor Data Concentrator (PDC) = $135k per gateway
- Install new station Local Area Network (LAN) infrastructure = $280k per station voltage level

If generating stations do not anticipate any internal applications for the PMU data and are willing to directly stream the collected information to the IESO infrastructure, they may avoid the PDC costs. Furthermore, costs may be further reduced by deploying site-to-site communication through existing Virtual Private Network (VPN) channels. Accordingly, telecommunication costs will be reduced significantly for generating stations. However, more accurate estimation is only achievable by considering the unique requirements and available resources for each MP.

Security (S):

The second most significant factor affecting PMU installation costs is cybersecurity requirements. The cybersecurity cost varies based on the adopted strategy. The IESO is taking a staged strategy to first benefit from PMU data for offline applications in the short-term and to then extend its use to real-time applications in the long-term. Accordingly, MPs are recommended to consider how to most cost effectively meet both the short-term and long-term PMU requirements. A strategy focused on the short-term could allow transmitters to reduce their near-term security costs while adhering to the less demanding North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP[5]) requirements by only monitoring system conditions and improving their offline capabilities, however may necessitate further investment at a later date. Whereas, a long-term comprehensive strategy would require additional upfront investment, but would allow transmitters to comply with the more extensive NERC CIP requirements by deploying PMUs as a critical cyber asset for making operational decisions and taking automatic control actions.

Similarly, for generators, IESO's expectations for eventual use of data and anticipated compliance with NERC CIP requirements will have a direct impact on the respective generating stations and the cost they are bearing to provide synchrophasor measurement data. VPN communication system can meet the PMU requirements in short-term. However, as PMU data usage evolves into the IESO's real-time applications with a greater number of measured signals to be transmitted, a dedicated circuit may be required based on assessment of the existing systems for each generating stations.

[5] NERC Critical Infrastructure Protection compliance website: https://www.nerc.com/pa/Stand/Pages/CIPStandards.aspx. NERC continues to update CIP requirements in response to evolving threats and technology capabilities.

Labor (L):

To minimize the labor costs associated with PMU installation, transmitters may adopt either a specialized or a decentralized crew strategy and coordinate PMU installation with planned substation outages. To come up with the optimum strategy, one may consider the extent of geographical territory and the number of PMUs to switch between trainings for one crew and across the system. The cost associated with the labor efforts depends on the number of PMUs to be installed, distance to the sites, installation methods, and the crew's experience level. When transmitters target installing and upgrading 50 or more PMUs, a standardized process for PMU installation may shorten the work time and hence reduce total labour expenditures. Operational costs are another aspect of the labor costs to be considered for the PMU adoption by the MPs.

With smaller geographical territory and fewer number of PMUs, generating stations and renewables are expected to have much lower labor cost.

Equipment (E):

The final cost factor accounts for approximately 5% of the total synchrophasor installation costs and accordingly the lowest cost driver among the four factors. The existing equipment strategies include:

- Acquiring and installing new stand-alone phasor measurement units
- Replacing existing digital relays or Digital Fault Recorders (DFRs) with plug-compatible equipment with PMU functionality
- Upgrading software/firmware for existing digital relays or DFRs to enable PMU functionality

A combination of these strategies can optimize the overall equipment costs. Wherever possible, leveraging multiple functions within a single installation is a more cost effective option. If dual-function devices are not already installed, stand-alone PMU units tend to be a more attractive option.

Followings are three possibilities for estimating the costs associated with the cybersecurity protection (S), labor expenses (L) and equipment (E) using Intelligent Electric Devices (IEDs):

Total estimated cost for S+L+E:

- Enable PMU on existing IED = $15k per IED
- Upgrade protection IED to provide PMU = $50k per IED
- Install separate PMU IED = $167k per IED

Finally, considering all four factors, the overall PMU installation cost (IC = C + S + L + E) range is estimated to be between $50,000 and $300,000 for transmitters (transmission stations) and between $25,000 and $200,000 for generators (generation stations).

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