Summary Schedule of Program Elements

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Program Element I: Performance Validation of µPMU: The project team will verify and improve the performance of the µPMU hardware platform so that it reliably meets performance criteria under field conditions. ***Specifically:*** *Determine minimum requirements, and demonstrate with laboratory testing and a pilot installation that the µPMU instrument meets the requirements. µPMU certification to UL61010 safety standard, IEC 61000-4-30 measurement standard, and IEC 62053-22 and ANSI C12.20 accuracy standards.*

Program Element 2: Networking - µPnet: The project team will develop a live network of µPMUs, which we call micro-phasor-net, or µPnet, capable of supporting key applications to enhance diagnostics, situational awareness, and ultimately control capabilities in power distribution systems. The initial installation will be at the pilot test site on the UC Berkeley campus. ***Specifically:*** *Develop a network of µPMUs, called "µPnet", capable of supporting key applications: diagnostics, situational awareness, and control capabilities in distribution grids. Conduct a pilot µPnet installation.*

Program Element 3: Empirical Circuit Studies This task has the simultaneous goals of (1) field testing the µPMUs in aggregate, (2) collecting new information about the behavior of distribution circuits, (3) validating distribution circuit models, and (4) testing the hypothesis that voltage angle data provide unique insights to phenomena on distribution circuits. ***Specifically:*** *Field test approximately 100 µPMUs, and use them to collect new information about the behavior of distribution circuits. Include some circuits that include a high penetration of Distributed Generation. Use collected data to validate distribution circuit models, and test the hypothesis that voltage angle data provide unique insights to phenomena on distribution circuits.*

Program Element 4: Study of Diagnostic Applications: The team will evaluate the use of µPMU data to support specific diagnostic applications on distribution circuits. Task IV focuses on the timely detection of specific problems known to be of concern to utilities and likely to impact electric power quality and reliability for customers. ***Specifically:*** *Evaluate how µPMU data can support specific diagnostic applications on distribution circuits. Focus on timely detection of specific problems known to be of concern to utilities, and likely to impact electric power quality and reliability for customers. Specify communication requirements for each diagnostic application.*

Program Element 5: Study of Control Applications: The team will evaluate the use of µPMU data to support specific control applications on distribution circuits, including microgrids. Task V addresses *control actions* that might be taken in response to information provided through µPnet. µPMU data will be converted into actionable, operational intelligence and propose supervisory control signals that could ultimately be implemented in either open-loop or closed-loop control schemes. ***Specifically:***

Evaluate the use of µPMU data to support specific control applications on distribution circuits, including microgrids. PE4 focuses on identifying distribution circuit phenomena. In contrast, PE5 addresses control actions that might be taken in response to information provided through µPnet. PE5 will assess how µPMU data might be converted into actionable, operational intelligence, investigating how propose supervisory control signals could ultimately be implemented in either open-loop or closed-loop control schemes. Of particular interest are control applications that are likely to enable increased economical distributed energy resources (DER), and are likely to improve power quality and reliability for customers in the presence of DER. PE5 will use modeling to examine and demonstrate the effectiveness of proposed supervisory control strategies through modeling. In particular, PE5 will evaluate the operational flexibility that might be afforded by µPMU-based control. (Actually implementing any of these control applications is outside of the scope of this project.)

Program Element 6: Technology Transfer & Outreach / Commercialization This task has two separate goals: (1) commercialize the µPMUdevice technology of PE1, and (2) commercialize the network, software, and algorithms of PE2, PE3, PE4 and PE5. The µPMU commercialization timing will be aggressive, because the platform exists and the Technology Readiness Level is high. At utilities, Bench Tests and Pilot Projects could operate in parallel with (and even feed data into) this Project. Task 1.7 supports these activities. Stage (2), Commercializing efforts for Tasks PE2, PE3, PE4, and PE,5 will commence in Year 3 of this Project, because the characteristics and value of these elements will not be fully known until near the end of this 3-year project, and the Technology Readiness Level is much lower for the applications than the device. Two deliverables, a Market Plan and a Commercialization Plan, are created for PE2-PE5 in Year 3, in addition to active outreach. These plans will, in general, follow the methodology shown for µPMU commercialization in Year 1, but details will be filled in when the results of PE2-PE5 become clear.