Grid Edge Control: A New Approach for Volt-VAR Optimization

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***Abstract*—A new approach to achieving volt-var control through the use of fast-acting distributed hybrid power electronics devices at the grid edge is proposed. It is shown that there is a missing layer of control at the grid edge which the conventional approaches do not address. Through field demonstration of 91, 10 kVAR devices on a 13 kV, 6 MW feeder, up to 5% CVR, 72% reduction in voltage volatility, 80% reduction in voltage unbalance and feeder level dynamic var control using the proposed grid edge control is presented.**

***Index Terms*—Volt-var control, volt-var optimization, electric distribution system, grid-edge, distribution automation**

I. Introduction

Under the American Recovery and Reinvestment Act (ARRA) of 2009 to modernize the US electric grid through deployment of smart grid technologies, the US Department of Energy has pumped almost $4.5 billion with a total value of $8 billion which includes contribution from the electric industry. Of this, $2.5 billion has been spent on distribution automation, volt-var control, conservation voltage reduction, energy conservation, peak demand reduction, and AMI deployment. With 200 participating utilities, this has been the single largest fund dedicated to modernizing the electric grid till date [1].

Duke Energy, reporting on the results of their ARRA deployments, shows that $155M/year in savings, representing 41% of the total savings came from voltage reduction, a direct use of volt-var control (VVC) techniques [2]. Other examples, such as Dominion's case to their regulators for a $500M AMI deployment showed that 80% of the economic justification was based on demand reduction and energy conservation based on VVC. Another study from McKinsey projects that $43B out of a total $63B in annual 'grid applications' benefits comes directly from VVC [3]. An additional $59B/year in benefits relate to peak demand management, energy conservation and avoided cost of new generation capacity – many of which can be impacted with volt-VAR optimization (VVO). It is abundantly clear that the economic justification for grid modernization often rests on using VVC as the vehicle to deliver improved system capacity, efficacy and revenues, while at the same time reducing operating and capital expenditures.

Even though VVC forms the majority of grid modernization return on investment, most of the utilities today are limited to achieving no more than 1-2% of control through conservation voltage reduction. This is due in part to the limited visibility on the secondary side of the grid, and the sparsity of control handles present in the form of line capacitor banks (LCB), line voltage regulators (LVR) and load tap changers (LTC) on the system. Further, the variability on the system arises on the secondary side of the distribution grid contributed by the dynamics of loads. However, the control resides on the primary side. Therefore, there is a missing layer of control on the secondary side of the grid, termed as the "grid-edge". In most cases, the voltage drops across the service transformers and the variability on the secondary side have been ignored or considered negligible. With increased AMI deployments, all these deep rooted assumptions are being proved wrong. Further, with the advent of distributed solar on the electric grid, the problem of voltage volatility and therefore VVC is becoming more complex. Consequently, a loss of VVO benefit is felt.

This paper introduces a new concept of achieving VVO through Grid Edge Volt-VAR control with the use of distributed dynamic power electronics devices that operate autonomously on the secondary side of the distribution system and eliminate the nasty variations that are seen due to poor power factor loads and other grid disturbances. A swarm of these grid-edge VVC controllers can act in unison to tame the grid into a well-behaved system and unlock a simple grid-edge VVC scheme to achieve 5-7% of energy and demand control, increase system efficiency by 10% and even provide feeder level dynamic lead-lag var control.

II. Limitations of Current VVC Approaches

Volt-VAR control can be broken down into three parts – *Sensing, Computing, and Control (or Actuation)*. In traditional Volt-VAR control methods, sensing occurs generally on the primary side where parameters such as, voltage, current, real and reactive power are measured. Information on these parameters is obtained either from the substation or through sparse locations on the network, generally at reclosers or cap banks along the feeder. One can imagine that the number of sensed parameters is generally in the range of 3-5. Recently, AMI data is being leveraged by some utilities and companies [4]. Even though AMI data seems to be the best "sensed" dataset one could use, there are some challenges associated with it. More often than not, voltage is not reported in addition to the kWh data. Even if reported, the rate at which AMI data is sent is generally in the 15 min to 1 hr range at best, sometimes as low as once or twice a day. Further, the voltage measured by most meters is a few cycle RMS (16 cycle is a

[7] R. Moghe, D. Divan, D. Lewis, J. Schatz, “Turning Distribution Feeders into STATCOMs” accepted in IEEE Energy Conversion Congress and Exposition (ECCE), 2015.