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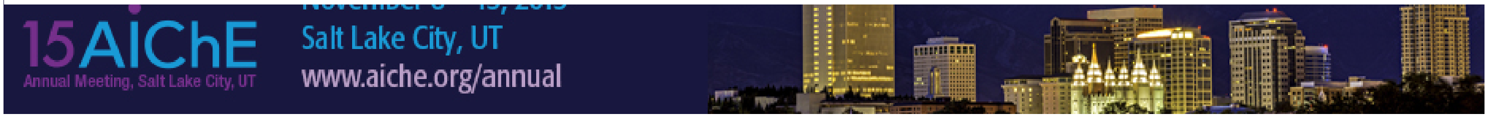

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423126 Addressing Control Challenges of Discontinuous Processes with Multi-Fidelity Model Predictive Control

Wednesday, November 11, 2015: 2:36 PM
Salon E (Salt Lake Marriott Downtown at City Creek)

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Petroleum currently fulfills 32% of total national energy demand, more than any other source of energy, and is likely to continue to do so for at least the next 30 years[1]. While the need for alternative sources of energy is clear, the growth and maturity of renewable energies has been slow and unable to meet energy demands, especially in transportation. Therefore, to meet the growing demand for energy, more efficient, robust, and reliable technological advances are needed in the petroleum industry. The petroleum industry is historically divided into upstream and downstream divisions. The upstream division finds and extracts oil and gas from geologic formations, while the downstream division refines the crude oil and gas into usable products. The downstream sector has seen many technological advances in process control and optimization, but many processes in the upstream sector, such as oil well drilling, still lack any significant automation[2]. When automation is optimized, it improves safety and efficiency over manual control by responding faster to process disturbances and by operating closer to process constraints. However, a unique challenge of automating Managed Pressure Drilling (MPD) for oil and gas is the discontinuous nature of the process[2]. An oil or gas well is created by drilling into the earth for several hundred to several thousand feet, stopping to insert and cement in place a segment of casing pipe to the well bore, then repeating the process until the target depth is reached. Before the casing pipe is inserted into the well bore, the string of drill pipe must be removed from the well, set aside, and then placed back in the well to resume operations. As the well deepens, more drill pipe is connected to the drillstring. At the bottom of the drillstring, a Bottom Hole Assembly (BHA), consisting of measurement and steering equipment, is attached to the drill bit. The drill bit is cooled by the drilling fluid, or mud, which also moves the rock cuttings to the surface and maintains pressure in the well annulus (see Figure 1). The well annulus pressure consistently needs to be greater than the geologic reservoir pressure to prevent hydrocarbons from entering the well during the drilling process. If the mud pressure in the well is too high, it can damage the rock formation; if it is too low, hydrocarbons from the subsurface reservoir can come to the surface in an uncontrolled and dangerous manner. When this catastrophe happens it is known as a blowout. The well bore pressure must be maintained within a small range of pressures that balances the reservoir fluid pressure to prevent damaged formations and blowouts. Maintaining the pressure balance in the well is the goal of MPD[3].

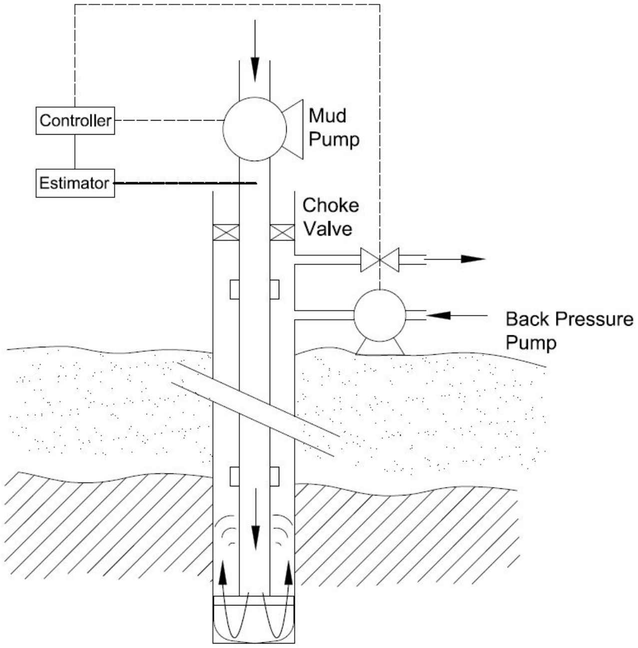

Figure 1 A simplified diagram of the MPD process

Currently, industrial MPD is completely manual. However, it has been demonstrated that an automated controller can maintain borehole pressure and reject disturbances faster and more accurately than manual control by using Nonlinear Model Predictive Control (NMPC)[4]. A controller can coordinate the mud pump flow rate and the annulus choke valve opening to reach the desired bit pressure set point[5]. One of the challenges with automated control of MPD is the necessary stopping and starting of operations. This discontinuous process can cause pressure sensors in the drillstring and BHA to lose calibration and controller models to lose tuning in the intervals. To address these challenges, this work simulates multiple control models arranged in an ensemble control structure to maintain control over various process stages: normal drilling operations, pipe reconnection procedures, and the disturbance of unwanted gas influx from the reservoir to the well bore. The novel control structure allows switching among control models of varying accuracy. A high fidelity model of the process is used when available, but the long computation time makes it unavailable for every control instance. The faster and less accurate low-order first principles model is the primary controller, yet it may not converge to an optimal solution at every time step due to the use of dynamic parameter estimation using Moving Horizon Estimation (MHE). An empirical First Order Plus Dead Time (FOPDT) model generally converges to an optimal solution at each time step, yet it is the least accurate model available. The controller makes use of these multi-fidelity models based on the availability and accuracy of the past model predictions compared to the current process state. The model solution with the least error is used to control the process at the present control instance. A limitation on the rate of change of process inputs is set to avoid sudden jumps when switching between models. An additional benefit of this control structure is the ability to tune one model while another is being used to control the process. Thus, model tuning can be accomplished without interrupting the drilling process[6]. Hence, the redundant model control structure offers benefits typically associated with redundant process measurements. This novel ensemble controller is capable of maintaining control over the discontinuous MPD process.

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