Dome Drive Electrical VFD System Upgrade

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APPENDICES

15-03-001 Dome Drive Electric Upgrade Requirements (Metric units)

The following document outlines the requirements for the dome drive system electrical motor upgrade. Requirements are listed in the following order:

Requirements (goals)
Reference information-justification

NOTE: During the integration of the electric motors to the gear train it was discovered that the original documentation, manuals, and specification identification plates were incorrect; the correct gear ratio is 1:80 not 1:140. The document below has been corrected to reflect the correct value.

Operational Requirements

1. Individual dome wheel torque needed to rotate the dome, 2.0 x 10 ^4 N*m
   1.1. Ref appendix A, section 14.
2. Individual motor torque needed to rotate the dome, 6.5 N*m
   2.1. Ref appendix A, section 15.
   2.2. Motor torque measured at the motor output shaft required to start the dome motion in either direction from a fully stopped condition. Torque shall be able to overcome the following:
   - Torque need to overcome static friction per wheel (track misalignment and roller stiction), 828.89 N*m
     - Ref appendix A, section 9, 10, and 11.
   - Torque needed to accelerate the inertial dome mass per wheel (from rest to full speed in 10 sec), 1.7 x 10^4 N*m
     - Ref appendix A, section 12 and 13.
   - Wind loads of up to 50 knots
     - Ref appendix A, section 25.
   - Mass moment of Inertia for the dome, 3.39 x 10^7 kg*m^2
     - Ref Appendix A, section 7 and 8.

3. Full operating slew speed of 60°/min (goal-slew speed of 72°/min only if future engineering demonstrates potential for safe operation at this speed).
   3.1. The target rotation speed expected of the dome under normal operating conditions, 60°/min.
   3.2. Rotational speed tolerance of ±2°/min.
   3.3. *Ref: Minimizes overheads for observations*
   3.4. *Ref: Appendix B – Dome drive data 2-17-2010*

4. Maximum intermittent or momentary slew rate shall be 70°/min (goal-slew speed of 75°/min only if future engineering demonstrates potential for safe operation at this speed).

4.1. The maximum speed of the dome at any time under any conditions, 70°/min.
4.2. Ref: The maximum rotation speed of the dome acceptable to prevent unnecessary wear and tear on the drive train in absence of verified calculations or measurements, 60°/min.

5. Ability to rotate the dome with two or three motors in operation
   5.1. The drive system shall be able to rotate the dome at 30°/minute with only two drives functioning.

6. Drive acceleration/deceleration and skid limits 0.00175 rad/sec^2 (60°/min/10sec).
   6.1. The acceleration/deceleration profile for dome rotation must prevent slip or skid of the drive wheels.
   6.2. *Ref: Appendix A, section 13.*

7. If an emergency stop is pressed the steepest deceleration profile possible will be applied to stop the dome rotation without skidding.
   7.1. If the dome is not turning when the emergency stop is pressed, the dome will be prevented from rotating.

8. Dome must not be allowed to rotate in a motor controller power off condition.

9. Building power failure
   9.1. Failed state of the parking brake system
      - When power is removed from the system the parking brakes are engaged (applied).
      - When power is applied to the system the parking brakes are disengaged (removed).

10. During normal operation the dome wheel shall be loaded onto the dome track with 24465 N of force measured at the wheel
    10.1. The actuator applies force to provide the required wheel friction on the track to reduce slippage.
    10.2. *Ref: Excessive downward force on the wheel is not desirable as it may deform and change the size of the wheel.*
    10.3. R*ef: Appendix E, section 3.1and 3.2.2.*

11. The drive wheels shall be able to be lifted off the track by 75mm
    11.1. The drive wheels need to be able to be lifted off the track for maintenance and repairs in the case of failure.
    11.2. R*ef: Appendix E, section 3.1and 3.2.2.*

12. The temperature operating range of all mechanical components in the design shall be -15°C to 20°C.
    12.1. Ref: Appendix F

12.2. Ref: Appendix G

13. Electronic components shall be housed to ensure they stay within their temperature operating range.
    13.1. Ref: Appendix F
    13.2. Ref: Appendix G

14. All electronic components (including motors and motor controllers) shall be de-rated by a minimum of 32.42% for an altitude of 4200m (14,000ft)
    14.1. Ref: Appendix A, section 18.
    14.2. Ref: Appendix F,
    14.3. Ref: Appendix G, section 3, receiving and Installation 3-1.

15. To minimize optical turbulence due to heat dissipated in the 5th floor observing environment, the heat dissipated shall not exceed 50W per motor over an average 30 minutes of normal nighttime operations (goal is 0W dissipated)
    15.1. *Ref: Goal is to keep the heat dissipation to less than a one person equivalent.*
    15.2. *Ref: Appendix A, section 19 and 20.*

16. The electric dome drive system energy consumption must be equal or less than the current hydraulic drive system
    16.1. *ref: must provide some energy savings as required by executive*

Motor requirements

17. One motor will drive one drive unit
    17.1. Each motor will drive its own drive unit.
    17.2. *Ref: Existing mechanical implementation of the drive units.*

18. Drive motor load or speed equalization must be implemented.
    18.1. Requirement to distribute the load evenly so the drive units do not buck or bind.
    18.2. Motor control must be able to support speed or torque following.
    18.3. Ref: Appendix G, section 3, receiving and installation 3-28

19. The reflected moment of inertia from the dome and drive train shall be approximately equal to the motor rotor inertia.
    19.1. Balancing the moments of inertia will provide the best efficiency for servo stability.
    19.2. An overall balanced or roughly equal inertia value pushes the resonance frequency out to a greater bandwidth.
    19.3. Ref: Appendix A, section 17.

20. Motors will be sized to account for the following:
    20.1. Dome acceleration, 1.745 x 10^-3 rad/sec^2
    - *Ref: Appendix A, section 12.*

    20.2. Dome static break free torque, 2.487 x 10^3 N*m
    - *Ref: Appendix A, section 9, 10, and 11.*

    20.3. Dome shutter lateral wind loads of 50 knots opened.
    - *Ref: Appendix A, section 25*

    20.4. Drive train maximum power transmission rating, the Brevini gearbox is the limiting component.
    - *Ref: Appendix A, section 21.1, and 22*

    20.5. Motor altitude de-rerating, size 32.42% larger.
    - *Ref: Appendix A, section 18*

    20.6. Motor controller altitude de-rating, size 32.42% larger.
    - *Ref: Appendix A, section 18.*

    20.7. The drive system and electric motors will be sized to operate under a 2 or 3 motor configuration.
    20.8. Each electric motor will be sized with an additional safety factor of, SF=2.5-3.

Drive motor shaft input and dome wheel output requirements

21. The total gear reduction of the drive system is 3660:1.
    21.1. *Ref: Appendix A, section 3.*
    21.2. Gear reduction of the Brevini transmission gear reduction box is 80:1
    - *Ref: Appendix A, section 2.*

    21.3. Gear reduction from the dome wheel to the track is 45.75:1
    - *Ref: Appendix A, section 1.*

22. The response time for the dome to reach full rotation speed from rest shall be 10 seconds or less.
    22.1. *Ref: Appendix A, section 5.*

23. The response time, acceleration and deceleration profile curves shall be adjustable from the motor controller.
    23.1. *Ref: Appendix H, Vector drive profile plot pg 5.*

24. The maximum torque delivered from the motor/motor controller shall not exceed the designed safety rating of any component in the drive system.
    24.1. *Ref: Appendix A, section 21.*
    24.2. *The Brevini Gear Reduction Box is the week component in the drive train.*
    - *Ref: Appendix A, section 22.*

25. Under operation with two motors, the time to full acceleration shall be less than 15 seconds.
    25.1. Acceleration response will change accordingly if all motors are not operating.

26. Under operation with two motors, the full rotating speed can be reduced to 40 deg/min or less.

27. The time to a fully operable power on system from a no power state shall be 2 minutes or less.

Position control requirements

28. The dome drive system must be able to be controlled by the current telescope control system (TCS).
    28.1. The TCS sends dome rotation commands to the dome control PLC and receives feedback on the dome position from the dome position absolute encoder
    - *Ref: Appendix I, Modified Current PLC Interface.*

    28.2. TCS dome movements are accurate to within one encoder count (±0.16° or 38.94mm) or better.
    - *Ref: Appendix A, section 4.*

29. The dome drive system must be able to be fully controlled manually from the 5th floor.
    29.1. *Ref: Appendix I, Modified Current PLC Interface*
    29.2. Existing control from the 5th floor control panel allows dome rotation with approximately 0.10 deg accuracy or better.
    - *Ref: Appendix A, section 4.*

    29.3. *Ref: Positional requirement needed for accurate position of crane loads.*

Existing component requirements

30. The dome drive wheel and SHP transmission (planetary gear reduction box) must remain unchanged
    30.1. *Ref: - No identified need to change current configuration.*

31. The Brevini gear reduction box must remain unchanged
    31.1. *Ref: - No identified need to change current configuration.*

32. The dome position absolute encoder (located next to the stairs to the messine level of the 5th floor) must remain unchanged
    32.1. *Ref: - No identified need to change current configuration.*

OAP requirements

33. Remote control functionality required:
    - Turn on/off power to motor controller units (dome drive package).
    - System shut down in event of failure.
        - o Power off motor controllers and motors.
        - o Actuator remains in an unchanged state.
    - Emergency stop
        - o Regenerative braking
            - *Ref: Appendix H, pg 2.*
        - o Maximum deceleration
            - *Ref: Appendix H, pg 2.*

    33.2. The drive system must be integrated with the TCS and PLC control systems for autonomous operation
    - *Ref: Appendix I, Modified Current PLC Interface*

34. Remote monitoring of the dome drive system
    34.1. On/off state of motor controllers.
    34.2. Rotation speed of each motor.
    34.3. Amperage/torque of each motor.
    34.4. Failure state of motor controllers (detection and notification).
    - *Ref: Appendix I, Modified Current PLC Interface.*