anticipation will occur and will generate a signal which will pass to the derivator **58**. The curve in the box **64** is shaped to provide anticipation only in the low M_N forward thrust regime where rapid thrust modulation is required for take-off and landing.

Hence, since power lever can change very rapidly, the speed error and anticipation derivative can become very large magnitude – short time duration signals. To avoid loss of a portion of these signals due to unavoidable signal limiting these derivative signals are converted into smaller amplitude - longer duration signals. This is accomplished by providing a rate - limited first order lag and then computing the derivative of this lag output as shown in FIG. 3. The combination of summer **60**, high gain **61**, limits **62** and time integration **63**, form a rate limited first order lag such that the output from **63** follows the anticipation signal from box **64** with a defined maximum rate. It is obvious that the derivative of the time integration may be obtained from the input to the integration, thus the signal to the integration into box **63** is also passed through the anticipation gain **65** to yield the PLA anticipation signal.

The fan speed governor is basically a conventional proportional and integral control. This is mechanized in FIG. 3 by forming the speed error **66** from the difference between $N_{F\ REF}$ and $N_{F\ SENSED}$, then passing this error signal through a proportional gain **67** and integral gain **68**. A rate - limited derivative of the proportional signal is formed in essentially the same manner as used in the anticipation circuit, except that the integration **72** has magnitude limits to permit smooth transition from fuel limiting to speed governing. Specifically, the combination of **69, 70, 71, 72** form a rate-limited lag that is also magnitude limited in box **72**. The derivative **73** of the box **72** output is added to the speed integral signal from box **68** and the anticipation signal from box **65** in summation **74**. The output from summation **74** is a measure of the desired rate of change of engine fuel. This signal is passed to the fuel control and time integrated **76** (within the fuel constraints **75** scheduled in the fuel control) for effecting changes in metered fuel flow.

Referring back to FIG. 2, PLA and flight M_N are used in function generator **70** to generate a commanded steady state fan blade angle signal, B_{RSS}. The fan blade angle is adjusted in a suitable manner to achieve this B_{RSS}.

Likewise, the PLA and flight M_N are used in function generator **72** to create a commanded optimum fan exhaust nozzle area signal, A_{FSS}. It is apparent from the foregoing that PLA and flight m_N are used to schedule fan blade angle and fan exhaust nozzle area in order to optimize performance in the normal operating regime.

In order to assure that the fan operates without excursions into the surge range the function generator **74** is provided. This schedules A_F as a function of corrected

$$N_F \ \left(N_F/\sqrt{\Theta} \text{ where } \Theta = \frac{T_2}{\text{Standard value}}\right) \text{ and } M_N.$$

This generated signal, i.e., the output of function generator **74** is compared with the scheduled A_F signal generated by he function generator **72** by maximum selector switch **76**, permitting solely the higher of the two values to pass through, A_{FFWD}. The area of exhaust nozzles **20** (A_F) are adjusted in a suitable manner to achieve this area, A_{FFWD}.

Thus, by virtue of this invention fan speed, fan pitch and fan nozzle is coordinated in such a manner as to optimize TSFC in the normal flight regimes and to optimize thrust response at takeoff and landing modes. The control minimizes complexities by being compatible with existing types of controls that already have provision for preventing surge, overtemperature, include acceleration and deceleration schedules and have overpressure and overspeed limits necessary for gas turbine engine operation.

As was emphasized above, by virtue of this requirement of reversing through feather, the fan in order to accomplish this feature would increase thrust until feather position is reached as well as increasing the torque on the fan driving shaft. This, obvious, is counter to what is necessary for good braking characteristics that are desired for optimum short aircraft landing performance.

Thus, in order to obtain rapid reverse thrust without exceeding shaft torque limits and minimize any increased forward thrust excursions, the fan pitch, fuel flow and fan exhaust nozzle area are coordinated during the transition to reverse thrust. To this end, interlocks **44, 46** and **48** are included in the speed, blade angle and nozzle area circuitry. The interlock **44** includes a fan pitch (β) override, interlock **46** includes fan exhaust nozzle area (A_F), fan speed (N_F), fan pitch (β), and power lever angle (PLA) overrides and interlock **48** includes fan pitch, fan speed and power lever angle overrides so as to perform the following control logic.

When reverse thrust is requested by retarding the power lever angle to the reverse thrust range, the fan pitch is scheduled to go to its reverse pitch and fan nozzle area is scheduled to the reverse position. In order to minimize the increased thrust and shaft torque transient which results from increasing fan pitch, fan exhaust nozzle area is opened as rapidly as possible and fan speed reference is decreased which causes engine fuel flow to decrease to the deceleration limit. During this initial time interval fan pitch is either held fixed for a short time or allowed to increase at some relatively slow rate until the exhaust nozzle area has opened to a prescribed value and fan speed has decreased sufficiently to minimize the increased thrust transient. After the fan pitch has increased past the feather angle, the blades are allowed to go to their scheduled reverse angle at maximum rate and the N_F reference is restored to its normal scheduled reverse thrust speed.

The unreversing coordination of engine fuel flow, fan pitch and exhaust nozzle area need be slightly different to prevent fan overspeed and excessive shaft torque in the feather region. When unreversing thrust is requested by advancing the PLA to the forward thrust regime, the fan pitch is scheduled to go to its forward pitch position, and the fan nozzle area is scheduled to the position associated with forward thrust. The fan pitch is decreased to forward pitch as rapidly as possible, and the nozzle area is delayed at reverse area position to avoid fan surge in the feather region. The PLA signal, as used in function generators **50** and **56**, is temporarily reset to a lower power to avoid fan overspeed and excessive shaft torque while the fan pitch is moving from reverse to forward pitch. The PLA schedule returns to normal, and the exhaust nozzle area is