CONCLUSION

This paper proposed an active control strategy to reduce the impact of earthquake on a model of Bill Emerson Memorial Bridge in Cape Girardeau, Missouri. The model was created and had been used as a benchmark to study various structure control systems. The complexity of such structure is challenging for engineers to provide the solution to the problem.

The control systems proposed here used a total of 51 devices, spread across the bridge deck on 30 locations. The controller used active bounded control as its base to determine the forces required to adjust the dynamic properties of the structures.

As the eighteen criteria show, the proposed controller successfully reduces the bridge response to earthquake, compared to the uncontrolled response, except the shear at the deck level of the tower and the displacement of the deck with respect to the ground. This is due to the shock transmission devices being used to connect the deck to the tower. The numerical measurement of these values shows that the forces and displacement encountered are still within the boundaries, with extra measures to be taken when designing the structure.

As an active control system, the devices rely on external power sources, preferably from electricity. The power line must not be interrupted at all time, including the time when an earthquake happens in the area.

The relatively small force requirement and device stroke make this control system easy to be implemented with wide range of actuators. The devices can potentially be replaced with the semi-active devices, such as the MR devices. That way, the power requirement of the overall control system can be greatly reduced, even can be operated on batteries to avoid power failure during major earthquake.

The controller must be adjusted properly in order to avoid the instability of the structure by selecting the value of α for tanh(). An optimum value of α can be found by running the simulation for various combination of device peak forces and the values of α.

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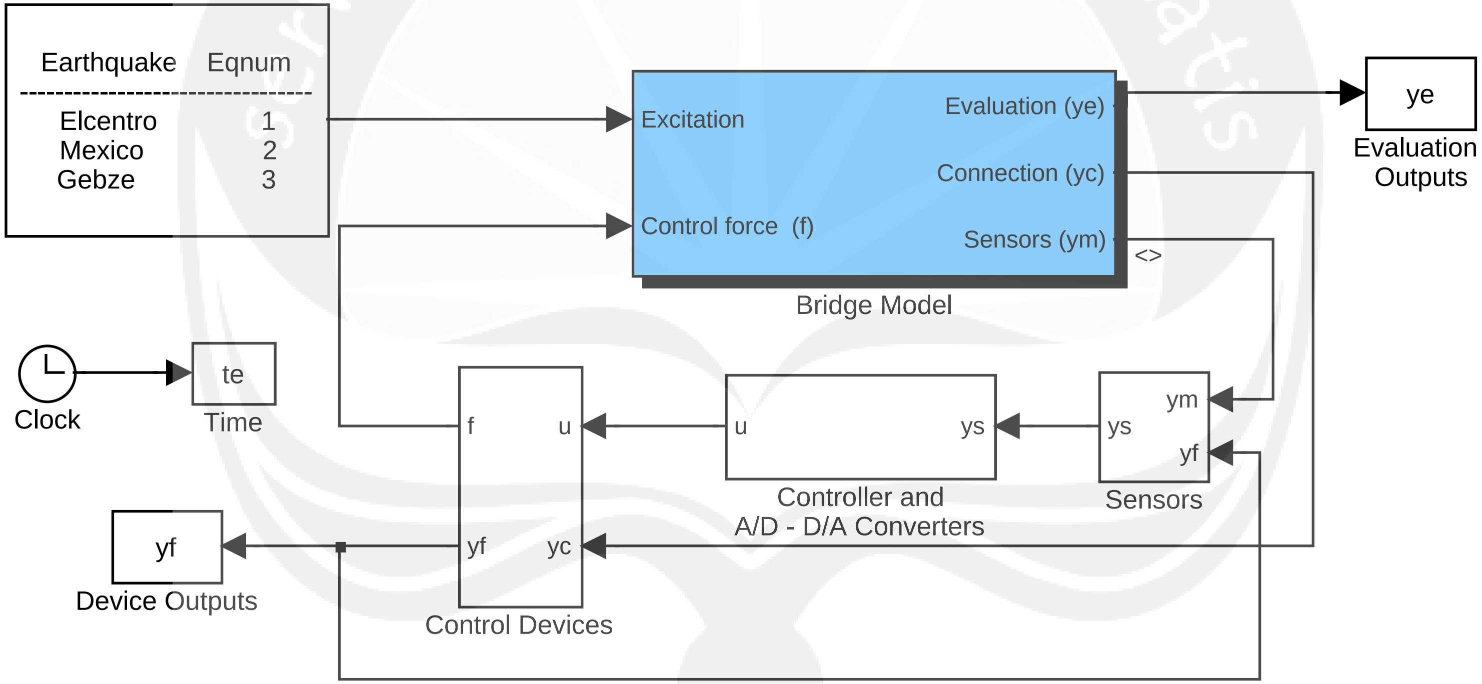
Appendix A

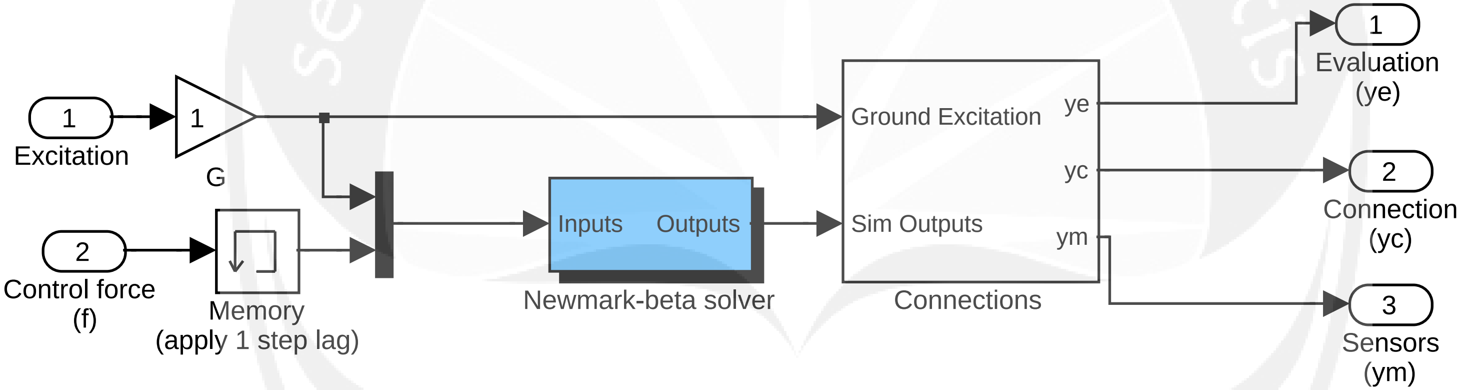
First Generation Benchmark Control Problem for Cable-Stayed Bridges

S.J. Dyke, G. Turan, J.M. Caicedo, L.A. Bergman, and S. Hague



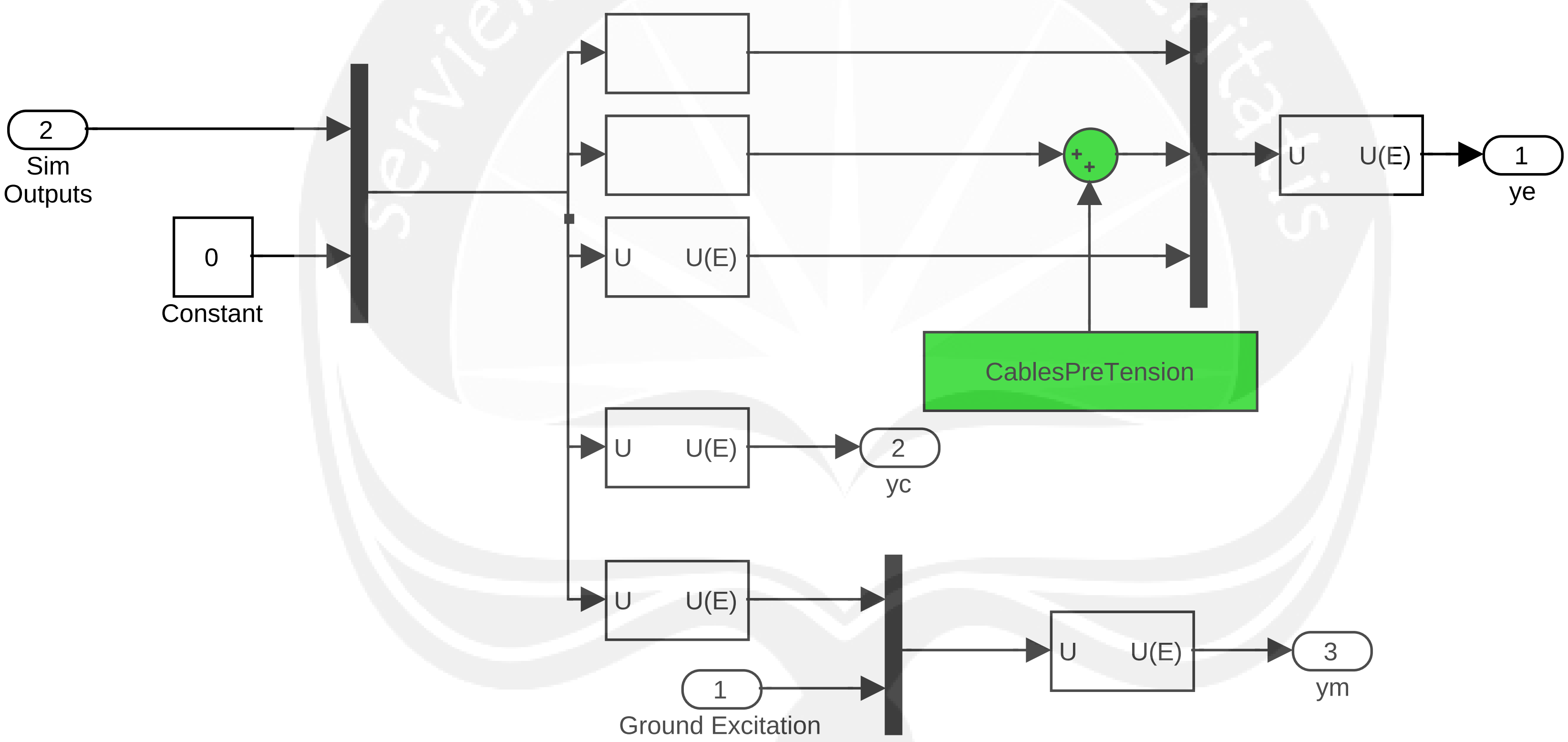
Simulink Bridge Model

S.J. Dyke, G. Turan, J.M. Caicedo, L.A. Bergman, and S. Hague



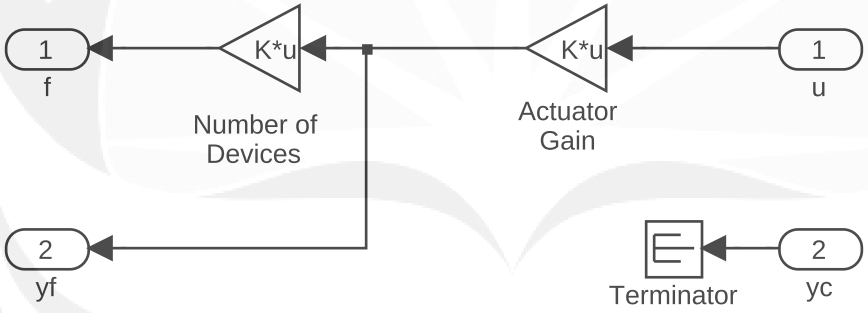
Connections

S.J. Dyke, G. Turan, J.M. Caicedo, L.A. Bergman, and S. Hague

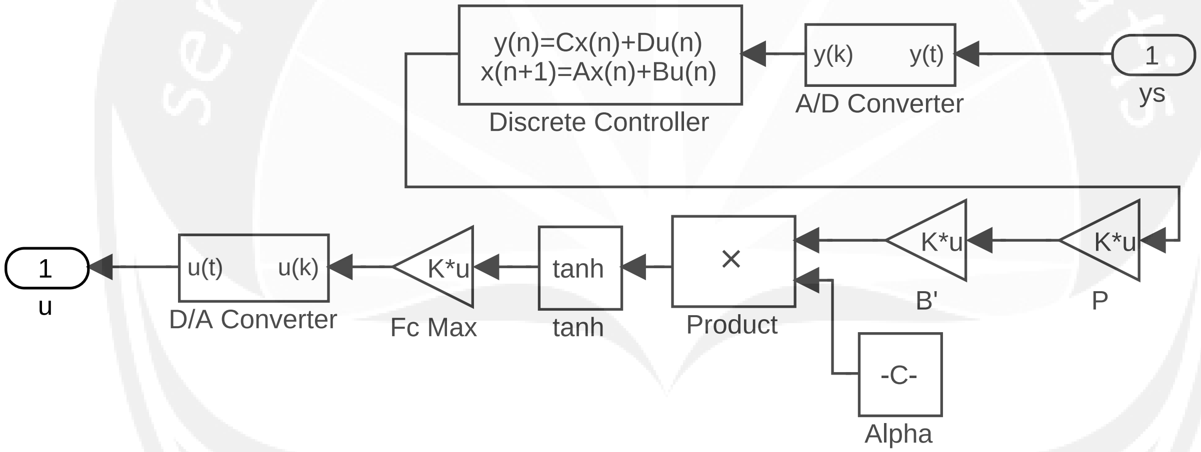


Control Devices

S.J. Dyke, G. Turan, J.M. Caicedo, L.A. Bergman, and S. Hague

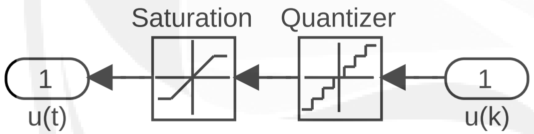


Discrete Control Algorithm with A/D and D/A Converters

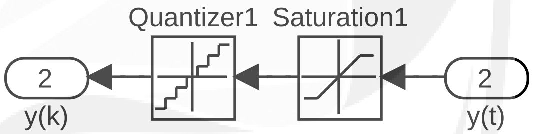


Converters

S.J. Dyke, G. Turan, J.M. Caicedo, L.A. Bergman, and S. Hague

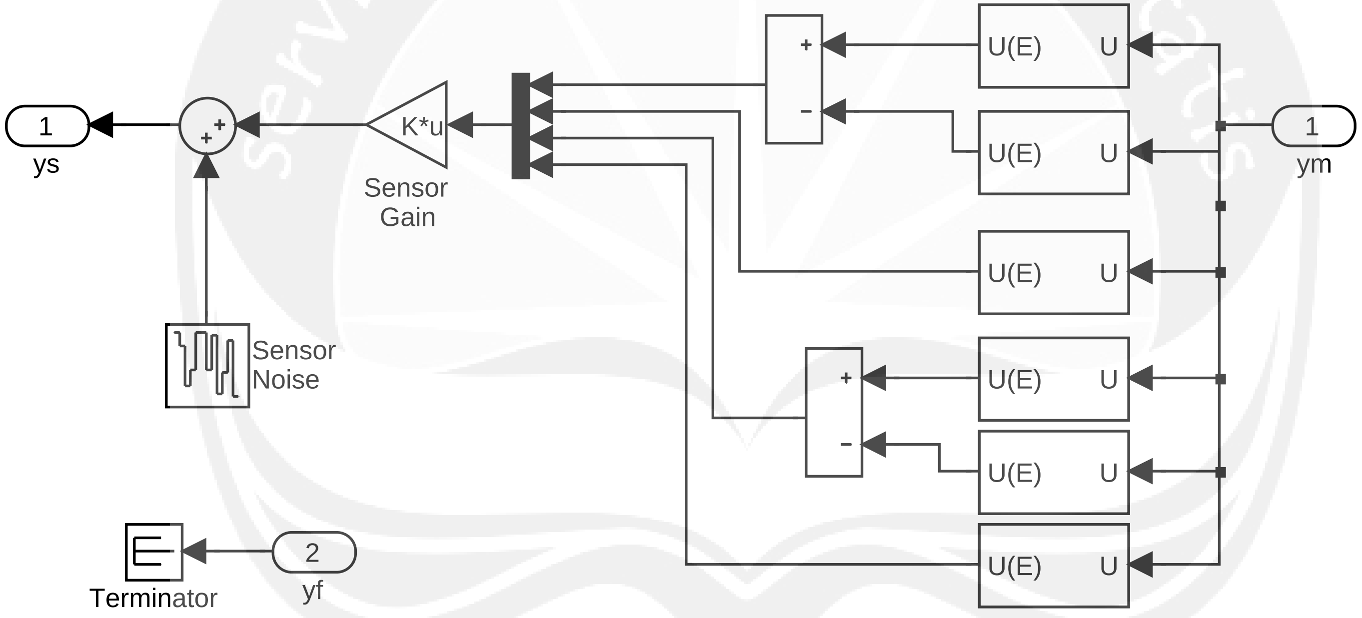


D/A Converter



A/D Converter

Sensors



Appendix B. Uncontrolled Peak Response

Uncontrolled Maximum Responses for Performance Criteria Calculations

(Dyke et al, 2002)

Response	Definition	El Centro U.S.A.	Mexico City Mexico	Gebze Turkey
F_{0b}^{max} (kN)	$\max_{i,t}\lvert F_{0bi}(t)\rvert$	4.8782e+4	1.1181e+4	3.0848e+4
F_{0d}^{max} (kN)	$\max_{i,t}\lvert F_{0di}(t)\rvert$	4.6712e+3	1.5248e+3	3.1497e+3
M_{ob}^{max} (kN-m)	$\max_{i,t}\lvert M_{0bi}(t)\rvert$	1.0271e+6	1.9824e+5	6.9779e+5
M_{0d}^{max} (kN-m)	$\max_{i,t}\lvert M_{0di}(t)\rvert$	2.2054e+5	8.6701e+4	1.0927e+5
x_{0b} (m)	$\max_{i,t} x_{0bi}(t)$	9.7583e-2	2.4324e-2	7.1916e-2
$\lVert F_{0b}(t)\rVert$ (kN)	$\max_{i}\lVert F_{bi}(t)\rVert$	5.2647e+3	1.4741e+3	2.6088e+3
$\lVert F_{0d}(t)\rVert$ (kN)	$\max_{i}\lVert F_{di}(t)\rVert$	4.5607e+2	1.889e+2	2.3124e+2
$\lVert M_{0b}(t)\rVert$ (kN-m)	$\max_{i}\lVert M_{bi}(t)\rVert$	1.1628e+5	3.1467e+4	5.7793e+4
$\lVert M_{0d}(t)\rVert$ (kN-m)	$\max_{i}\lVert M_{di}(t)\rVert$	2.0128e+4	6.9306e+3	9.5070e+3
x_0^{max} (m)	$\max_{t}\lvert x_0(t)\rvert$	0.14862	4.8302e-2	0.13117
$\dot{x}_0^{max}$ (m/s)	$\max_{t}\lvert \dot{x}_0(t)\rvert$	1.1795	0.32172e	0.61848

Appendix C. Information on Stay Cables

Service Load and Ultimate Load of Stay Cables

(Dyke et al, 2002)

Cable No. (See Fig. 2.2)	Finite Element No.	Service Load (MN)[a]	Percentage of Ultimate[b]	Ultimate Load (MN)
1, 64, 65, 128	157,189,221,253	4.94	39	12.58
2, 63, 66, 127	158,190,222,254	4.98	39	12.84
3, 62, 67, 126	159,191,223,255	4.59	39	11.62
4, 61, 68, 125	160,192,224,256	4.27	39	10.88
5, 60, 69, 124	161,193,225,257	3.97	39	10.15
6, 59, 70, 123	162,194,226,258	3.60	37	9.78
7, 58, 71, 122	163,195,227,259	3.30	36	9.27
8, 57, 72, 121	164,196,228,260	3.15	34	9.20
9, 56, 73, 120	165,197,229,261	2.83	35	8.18
10, 55, 74, 119	166,198,230,262	2.64	34	7.67
11, 54, 75, 118	167,199,231,263	2.58	35	7.26
12, 53, 76, 117	168,200,232,264	2.47	36	6.92
13, 52, 77, 116	169,201,233,265	2.40	36	6.58
14, 51, 78, 115	170,202,234,266	2.01	36	5.57
15, 50, 79, 114	171,203,235,267	1.78	35	5.06
16, 49, 80, 113	172,204,236,268	1.62	35	4.69
17, 48, 81, 112	173,205,237,269	1.46	31	4.73
18, 47, 82, 111	174,206,238,270	1.75	35	5.03
19, 46, 83, 110	175,207,239,271	1.98	36	5.51
20, 45, 84, 109	176,208,240,272	2.00	35	5.72
21, 44, 85, 108	177,209,241,273	2.41	36	6.73
22, 43, 86, 107	178,210.242,274	2.55	37	6.97
23, 42, 87, 106	179,211,243,275	2.73	36	7.50
24, 41, 88, 105	180,212,244,276	2.93	36	8.08
25, 40, 89, 104	181,213,245,277	3.15	35	8.97
26, 39, 90, 103	182,214,246,278	3.89	42	9.23
27, 38, 91, 102	183,215,247,279	3.80	38	9.90
28, 37, 92, 101	184,216,248,280	4.06	39	10.50
29, 36, 93, 100	185,217,249,281	4.30	40	10.78
30, 35, 94, 99	186,218,250,282	4.44	38	11.62
31, 34, 95, 98	187,219,251,283	5.05	39	12.88
32, 33, 96, 97	188,220,252,284	4.18	33	12.59

a. Service loads are determined through nonlinear static analysis.

b. Stay cables used in the Cape Girardeau have an ultimate strength of 1670 MPa and a 0.2% Proof Stress of 1520 MPa (Walther *et al*., 1988).